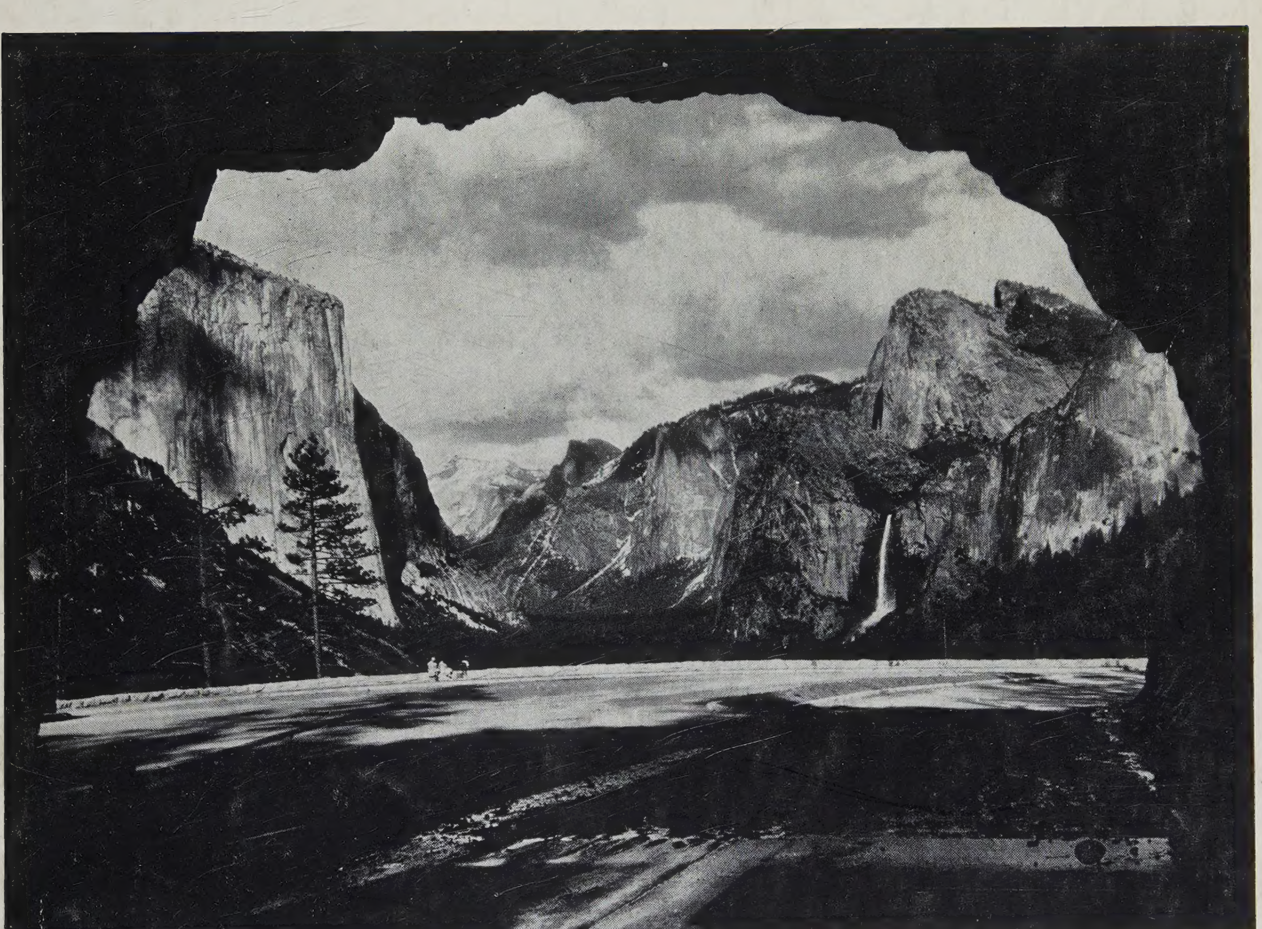
October
1933

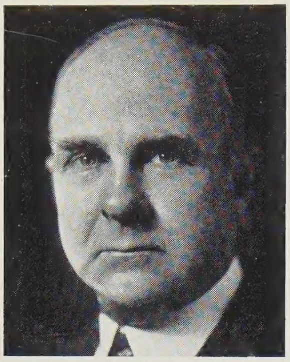
Electrical Engineering



Published Monthly by the
American Institute of Electrical Engineers

A Third Group of Institute Officers

The group of national officers newly elected for the year 1933–34 was presented in this space in the July 1933 issue. Part of the group of officers for 1933–34 whose terms hold over from the preceding year was presented in the August 1933 issue; the remainder is presented here.



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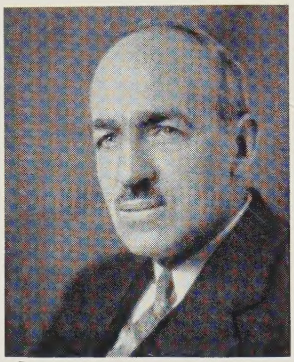

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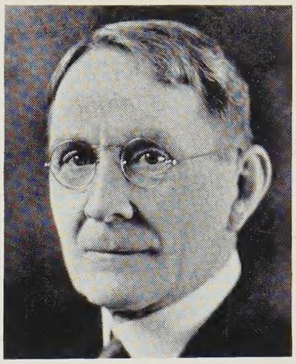

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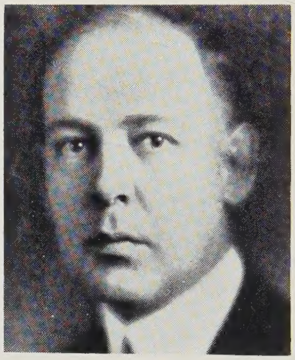

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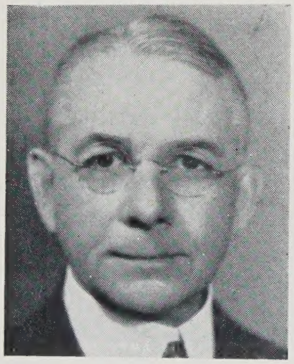

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Published Monthly by

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This Month—

Front Cover

Yosemite Valley viewed from the mouth of the Wawona Tunnel, Calif. This tunnel, 4,233 ft long and absolutely straight, is cut through solid granite. It has a 24-ft roadway and a 3-ft walk. Gas detectors automatically operate dampers and fans to insure pure air. General Electric Photo

—Turn to Next Page

IN OUTLINING the technical achievements of the past century, Dr. A. P. M. Fleming, local A.I.E.E. honorary secretary, England, says "engineering is the basis on which the magnitude and rate of progress depends." *p. 666–71*

LINE LOSSES should be taken into account in determining the most economical load division between generating stations, especially when these losses are large. *p. 674–7*

UNNECESSARY operations of protectors on low voltage a-c electric power distribution networks are eliminated by the application of a phase sequence relay. *p. 689–97*

A NEW insulating material for low voltage network cables has been developed that will withstand high temperatures. Faults in cables with this insulation will burn clear without producing smoke, or inflammable, explosive, or toxic gases. *p. 682–7*

HOW much light should be used in the United States to give the proper level of illumination for various purposes? *p. 716–19*

NOMINATIONS of A.I.E.E. officers for 1934–35 soon will be made; suggestions are solicited from the membership. *p. 720*

MODERN railway signaling as applied to an eastern road is described in this issue. Many features of this system are common to most modern systems. *p. 712–15*

AUTOMATIC train control has been applied to many railroads during the last few years. How the different systems are applied to 3 typical roads is described in this issue. *p. 698–702*

THE BLAST of vapor that issues at high velocity from the cathode region of a vacuum arc must be taken into consideration in formulating any satisfactory theory of the cathode of an electric arc. *p. 702–05*

IMPULSE voltage tests show that "surge proof" transformers should have a reasonable factor of safety between insulation puncture voltage and minimum bushing flashover voltage. *p. 678–82*

THE Engineers' Council for Professional Development "aims to coordinate and promote efforts and aspirations directed toward higher professional standards of education and practise." *p. 722*

MAXIMUM efficiency of a mercury arc rectifier is said to be obtained by operating at a higher temperature than ordinarily is used. Operation at the higher temperatures makes possible increased cooling efficiency. *p. 671–4*

EQUATIONS of motion describing the pulling-into-step transients of synchronous motors are solved readily and accurately by the "differential analyzer." From such solutions the pulling-into-step performance of practically any synchronous motor can be determined. *p. 707–12*

More About the Unified Publication Plan

ON THE front covers of the last issue appeared an important announcement outlining briefly a new policy that will govern A.I.E.E. technical publications. The purpose of this and possible subsequent articles is to enlarge upon these points so that the entire membership may be acquainted with the causes and effects of these changes.

Electrical Engineering to Be Enlarged

Enlarged to accommodate the inclusion of the full text of all formally recommended technical papers and the acceptable discussion thereon, the monthly publication will become the Institute's primary technical publication. It will continue to be distributed to every member of the Institute thereby providing a channel through which timely technical and other suitable material will be placed regularly in the hands of each member.

The new material to be added to the monthly publication will include all the officially recommended technical papers, technical committee reports, and discussions, heretofore available in complete form only in the quarterly issues of the A.I.E.E. Transactions from 6 to 9 months after original presentation, and from 9 to 12 months after their original preparation. Although some have not so realized, some 40-odd per cent of this material has been included in the monthly publication since January 1931. Now, however, all of it will be there and further discrimination in favor of Transactions subscribers will not exist. The program calls for the release of technical papers for publication immediately upon their logical completion and technical review, and irrespective of their possible inclusion on future District meeting or convention programs. This will eliminate the present serious overcrowding of meeting programs, and will make possible the wide distribution of a paper that is necessary for the stimulation of constructive and properly prepared discussion in time for meetings. Under the new publication policy, the formulation and execution of a properly balanced technical publication program will be definitely separated from, but of course correlated with, the planning and presentation of adequate, logical, and timely convention and District meeting programs that will be of the greatest possible general interest value to those that might be expected to attend in each case. Likewise, discussion on the technical papers, arising from their timely publication and wide circulation, will become available and can be published month-by-month. It is contemplated that written discussion on any live topic seldom, if ever, will be subject to arbitrary time limits. However, it is contemplated that the principal part of acceptable discussion on any one paper may be published in the issue perhaps 90 days succeeding the date of publication of the original paper. Thus, those who are interested in following the discussion of any topic will know about where to expect to find it. From the standpoint of future reference, the annual index, of course, will provide a complete system of correlation and cross referencing.

In addition to the formal A.I.E.E. technical papers, there will continue to be included in the monthly publication the full quota of special feature articles that have proved to be of such wide general interest since they were introduced in January 1931. The membership at large, and Section groups in particular, can be of material assistance to the Institute's publication staff by reporting sources of material of possible general interest to the membership.

In the news departments, primary attention will continue to be given to Institute matters, and to other matters of interest and importance to members. Suitable items reflecting activities of committees and of Sections and Branches will be published as available. Likewise, important information concerning other societies and, in response to a widespread demand, items covering the more important activities of members will be included. So long as there is sufficient demand to warrant it, the Letters to the Editor columns will be retained. For the sake of necessary economy, some of the routine departmental items that have proved to be of little general interest value will be eliminated or reduced to a minimum.

Quarterly Transactions to Be Eliminated

With the completion of volume 52 for 1933, the quarterly Transactions of the American Institute of Electrical Engineers will be discontinued as a separate publication and issued month-by-month through the pages of Electrical Engineering. Thus, those who have felt the need of subscribing to the Transactions, in addition to receiving the monthly publication, in order to have the full published record of A.I.E.E. technical material, will have no need to continue this added expenditure. For all who may wish to continue the accumulation of a library of bound volumes, there will be issued at the close of each year an annual volume cloth bound in a style similar to that previously used for the Transactions, embracing the material included in the 12 monthly issues.

The charge for this extra, in fact duplicate, service will be nominal, but it must at least make the annual volume a self-supporting undertaking. Because the printed sheets for the annual volume will be produced month-by-month, it is absolutely essential that all subscriptions to the annual volume should be definitely committed a year in advance. Thus, those wishing to secure the annual volume for 1934 must have a subscription commitment in the hands of the order department at A.I.E.E. headquarters by December 15, 1933, although payment will not be required until the annual volume is shipped. In other words, the annual volume will be supplied only on advance order.

Publication Committee

A Century of Development in Industry and Engineering

By A. P. M. FLEMING
MEMBER A.I.E.E.
Local Honorary Secretary A.I.E.E.
Metropolitan-Vickers Electrical Co., Ltd., Manchester, England

Citing engineering as the basis on which the magnitude and rate of progress depends, the author indicates the scope, and outlines some of the features, of the technical developments of the past 100 years.

INDUSTRY, which is the means whereby natural resources are converted into a form convenient for the use of man, depends for its progressive development upon engineering. It would be impossible today to maintain the teeming populations of the world at the present standard of living if the transformation of Nature's resources to finished products depended solely on manual effort. The power necessary for this purpose has been made available by engineering achievement. Further, it would be impossible to distribute the commodities without the facilities that power has provided. In the development and application of this great asset, science has been the creative faculty.

Every country has contributed to the Century's progress and it would be invidious to compare respective achievements but, for the manner in which for generations she has given free access to men of energy and pioneering instinct from every country and race, tribute is due to the United States.

1833

A brief survey of the world's industrial position in 1833 will serve as the base line from which some measure of the progress of the Century can be made. The principal industrial countries then were Great Britain, France, the United States, and Germany. Great Britain, due to her geographical position, mineral wealth, isolation from the then comparatively recent Continental Wars, and the early development of the steam engine and textile machinery, had the lead in engineering and in the principal industries of that day. In France, industrial development was hampered by financial and other difficulties, particularly internal transport. The tendency for England to consider America primarily as a source of supply of raw materials and a market for finished goods led to the restriction of the export of textile machinery for which she had become famous. The effect of this restriction, however, was to assist the development of industry in America.

In England and America most of the internal traffic was conducted by waterways, though attention was beginning to be paid to better road making. In Great Britain the position with regard to power engineering was such that the average size of steam engine was of the order of 25 hp with a maximum isolated instance of 110 hp. There was no electric power and no means of communication other than by direct contact or visible signal. Railroads were in their infancy and iron ships were rare and considered experimental. The application of steam power to other than railroads, mines, and textile mills was but slowly developing, and it is interesting to note that at the Royal Arsenal at Woolwich cannons were still being bored by a mill driven by 4 horses. Tools were limited, instruments of precision were completely lacking, measuring instruments were confined principally to the rule, calipers, and straight edge.

As compared with today, standards of living everywhere were relatively low, and in Britain particularly the concentration of workers in towns without adequate provision in housing, water supply, and sanitation, led to much squalor and ill health.

Steam Power

The Century is justly regarded as an age of steam power. Although the development of the reciprocating steam engine came earlier, its extended application, and the subsequent development of the steam turbine, the internal combustion engine, and the mercury turbine all came within the Century under review.

With all of its principal features tried and known, the development of the reciprocating steam engine after 1833 was largely concerned with improvement in details, refinement in design made possible as a result of the availability of superior materials and a more exact knowledge of their properties. During the Century the steam engine rose to its full development. Supplanted during the past quarter century by the steam turbine, and more importantly by the internal combustion engine which in horsepower and range of utility today easily holds premier position in the power fields, the steam engine is still supreme in the field of railway locomotion. The development of the dynamo which demanded high rotational speed exerted a powerful influence upon the reciprocating steam engine, leading to the development of high speed steam engines, and ultimately to their displacement for electric power generation purposes by the steam turbine.

The modern steam power plant dates its rise and development from the successful application of the steam turbine to electric generation, and later to marine propulsion. Although Parsons took out his first patent in 1884, it was not until 1891, when his turbine was operated with a condenser, that it was able to approach the reciprocating engine in economy. By 1900 steam turbines of about 1,000 hp had been constructed. By 1904 several units of 5,000 hp were in operation and one of 10,000 hp under construction. In the next year or so the superiority of the turbine

Abstracted from an address "The Development of Industry and Engineering During the Century" delivered before Section M (engineering) of the American Association for the Advancement of Science, Chicago, Ill., June 27, 1933. *Not published in pamphlet form.*

as a convenient and efficient prime mover for electric power generation was fully established.

Application of the turbine to marine propulsion was made by Parsons in 1897 when the 100-ton "Turbinia" was fitted with turbines of 2,100 hp driving 3 propeller shafts. Ten years later, battle cruisers were fitted with turbines of 41,000 hp, and the Cunarders, "Lusitania" and "Mauretania" were equipped with turbines developing 70,000 hp on 4 shafts. Just as the turbine has been responsible for condenser development, so also has it led to greater refinement and accuracy of reduction gearing and the development of high speed single and double reduction gears of large capacity. Electrical transmission in place of gearing has been applied to some of the largest vessels in the United States Navy, and to certain commercial ships. From the fact that some modern vessels are equipped with electric propulsion, whereas others now under construction are designed for mechanical gearing, it would appear that the respective fields for these methods still are undefined.

Despite the classical work of Carnot more than a century ago in determining the efficiency of the perfect heat engine, and Joule's enunciation of the principle of conservation of energy at the beginning of the Century, the development of steam prime movers did not receive intensive scientific treatment until during the last 15 years when a much closer study has been made of the factors underlying the economy of steam pressure and temperature and of the cycle of operations. The improvements that have been introduced are such that now the cycle of the turbine approaches the Carnot cycle. The idea of a binary fluid turbine already has been brought to a practical stage in the mercury vapor turbine, developed by Emmett of the General Electric Company, and the performance and experience of the power station at Schenectady, comprising 2 mercury vapor turbine sets each of 20,000 kw capacity, will be watched with interest.

The Internal Combustion Engine

As early as 1680 Huygens made a gun-powder engine in which a charge was fired when the piston was at the outer end of its stroke and a partial vacuum produced behind the piston as the resulting hot gas cooled. In 1820 a suggestion was made to drive an engine by an explosive mixture of hydrogen and air. At the commencement of the Century, Barnet proposed to use the compression of the charge, a practise since universally employed. An outstanding development in the internal combustion engine was the use of the Otto 4-stroke cycle in 1876, which cycle for gas and vapor engines has had no serious competitor since.

Diesel about 1895 developed the heavy oil-burning engine and surprised the engineering world by the unprecedented indicated efficiency he attained. The diesel engine is the most universal prime mover developed during the Century. In addition to its important application to marine propulsion and electric generation, it is used exclusively for submarines, has been employed upon airships, and is being tried out for aeroplanes; it promises to compete seriously with the petrol motor for heavy road vehicles and it has operated successfully certain kinds of railway traction service.

The magnitude of the range of size and utility of the diesel engine may be conveyed by the fact that an engine of 22,500 brake horsepower was constructed in 1932 for electric generation purposes. What the future of the heavy oil engine may be it is difficult to forecast. It is significant to note that in the field of marine propulsion, since 1927 the total new tonnage of the world employing diesel engines exceeds substantially the corresponding new tonnage driven by steam.

Water Power

Probably the oldest known form of prime mover is that using the energy of moving water. It is possible that the wonderful prime movers developed during this Century that are dependent for their motive power upon coal and oil may, with the exhaustion of the latter, be survived by the water turbine. Before and throughout the Century under review, water wheels were in common use for local power requirements. Some of these wheels were of a prodigious size, notably the Laxey water wheel of the Isle-of-Man, $72^1/_2$ ft in diameter and 10 ft wide, delivering about 150 hp.

Early water turbine development owes much to Fourneyron and Jonval in France, but the subsequent development, notably by Boyden and Francis, and the modern developments of the last 30 years occurred largely in the United States. The demand for large prime movers for electric power generation at low cost gave great impetus to this development. In the first Niagara Falls Power Company the water turbines comprised two units on the same shaft giving 5,000 hp at 250 rpm under a head of 135 ft. In the last third of a century water turbines have been increased in size to 90,000 hp (in the Dniepros-troi plant) and units of 100,000 hp are projected.

Reverting to the possibilities that water turbines may be the ultimate prime mover of the future, it is interesting to note from the latest surveys of potential water power in the world that 43 per cent is centered in Africa, notably in the Congo area. Hence, with the development of longer distance transmission and the husbanding and rationing of the world's power resources, the at present most undeveloped part of the world may become of the greatest importance to mankind in the future.

Electric Generators

Electric generation had its beginnings in the work of such pioneers as Oersted who discovered the effect of a wire carrying electric current on a pivoted compass needle, Arago and Davy who magnetized ferrous bodies with an electric coil, Sturgeon who invented the electromagnet, and Faraday and Henry who discovered the laws relating to magnetic induction. This work preceded the Century under review.

The first practical direct current generator took the form of a cylindrical iron armature whose surface

was over-wound longitudinally with insulated wire connected to a commutator, the whole being rotated on a shaft between the poles of a permanent magnet. The earlier developments in design were largely of a guesswork character; it was not until about 1886 that Hopkinson showed how to design dynamo electric machines on a scientific basis. In the meantime these machines were reaching a commercial stage. In 1881 Edison exhibited a bipolar dc generator at the Paris Exhibition and in 1882 he installed a 100-hp "Jumbo" machine in the Pearl Street station, New York. Machines of that day had to be tried out after they were built to see at what speed they should be run to give the right voltage and tested for the number of lamps they would light without overheating. The development of the steam turbine led to suitable modifications of the design of generator to take advantage of the high speeds then available.

The use of alternating current for other than local electric lighting purposes was not visualized until the serious development of the transformer took place. In 1882 Gaulard and Gibbs developed a power transformer, which invention was exploited by Westinghouse, who was quick to perceive the possibilities of the transformer in connection with long distance transmission.

At that time alternators had been developed to supply single-phase current, and the next development was the 2- and 3-phase systems of supply. The discovery by Tesla and Dobrovolsky of the rotating field effect producible by polyphase currents led to the development of the induction motor, and was an important step forward in the use of the alternating current system of power supply. Apart from the developments in the United States, the Ganz Co. of Austria, the Brown Boveri Co. in Switzerland, and Ferranti in England were engaged on alternating current developments. In 1891, the Frankfort Exhibition was lighted with 100 hp supplied from 3-phase generators installed at the Laufen Falls 110 miles away, the transmission being at a voltage of 8,000. The Columbia Exhibition at Chicago in 1893 was lit from alternating current two-phase machines. In 1900 Ferranti installed 10,000 volts single-phase power transmission between Deptford and London.

Generating voltages which, in the case of the original Niagara machines was 5,000 have reached a general level of from 10,000 to 15,000. Behrend's proposal of a quarter century ago for much higher generator voltage is coming into vogue; there are now several 33,000-volt generators. The use of suitable automatic voltage regulators has led to improvement in weight efficiency of the generators and their performance in respect to their effect on the stability of large interconnected networks. Improvements in reliability have been assisted considerably by increased knowledge of insulating materials, and weight efficiency has been improved as a result of advance in magnetic materials, thus emphasizing the importance of the contemporary development of applied science in another industry. Turbo-alternators of 200,000 kw have been constructed in single units.

Power Transmission and Distribution

The enormous demand for electric power has led to an investigation of all economical sources of energy, and the striking of an economic balance between the comparative cost of conveying fuel to a generating source place near the center of demand as against the transmission of electrical energy over a distance from points where coal or water power is readily available. The modern trend has been toward longer transmission distances and correspondingly higher voltages, and there are now in operation numerous transmission systems of 220 kv and some projected for 380 kv.

A possible rival to the transmission of electrical power by alternating current systems was that introduced by Thury a third of a century ago, in which he employed a number of direct current generators in series and obtained a high transmitting voltage. The possibilities of dc transmission at high voltages have been revived in recent years for very long transmissions (500 miles and upwards) and much research is being conducted on this problem in different parts of the world.

Transformers have undergone enormous changes during the Century. The early Gaulard and Gibbs transformers of 5 kw were considered of mammoth size. In 1900, a 2,000-kw unit was the largest in the world. Today units of 100,000 kw have been constructed, and there is no manufacturing limit to the output for which a single unit could be produced. In the materials employed revolutionary changes also have taken place. Transformers of a half century ago had magnetic cores of laminae of soft Sewdish charcoal iron. This gave place to soft sheet steel which possessed the unfortunate characteristic of rapid increase in magnetic losses with age. About 1908 Hadfield introduced silicon sheet steel which greatly reduced the magnetic losses and led to revolutionary improvement in the weight efficiency of transformers. Considerable improvement has taken place likewise in the design and manufacture of the insulating materials used, particularly the terminal bushings.

No branch of heavy electrical engineering has progressed so rapidly in recent years as have switchgear and the associated protective systems. In the very early days of small powers and low voltages, switches and fuses of a very rudimentary character mounted on wooden panels were considered adequate. A great advance, especially for high voltages, was the idea of breaking the circuit under oil instead of in air. The idea of obtaining a still higher degree of safety with large powers by completely enclosing all switchgear apparatus in a substantial metal casing filled with insulating compound has progressed rapidly during the last few years. In recent years, rapid progress has been made in advancing from the simple switch which functions by the mere separation of contacts. Important examples of new ideas introduced are the deion, the oil blast, and the air blast breakers. There is little doubt that further considerable advances will be made in the near future. The size and complexity of modern interconnected systems and the importance of stability in operation

have necessitated the provision of elaborate protective relay systems capable of a high degree of discrimination between faults of different types.

Uses of Power

A rough indication of the advancement during the Century in the use of power for transportation is the time taken for a person to cross the Atlantic. Exactly 100 years ago the first steam driven ship to make the trip, the "Royal William," crossed from west to east in 25 days. Modern ships make the crossing in about 100 hours; Miss Earhart crossed by air in 31 hr 30 min. Although vast improvements in convenience of passenger transport have been provided by modern railway development, the greatest ultimate benefit to the community has accrued from the industrial benefits that have arisen from the speeding up, increased turnover, and the consequent expansion of commerce. These benefits have been experienced in varying degrees in every country. In road transport the horse-drawn vehicles of 100 years ago have given way entirely to the automobile which began to appear about forty years ago.

A most significant application of power is in mining. Contrasted with 100 years ago when all excavations were done by manual labor, when the trucks from the coal face to the shaft were hauled by women or children, the use of mechanical or electrical means of winding and hauling is an enormous advancement. Today the use of electricity in mines has become general for coal cutting, conveying, hauling, and winding to the surface, as well as pumping, ventilation, and illumination.

Next to transport, communication has been the most important factor in the development of commercial and social life, and its history presents one of the romances of the Century. In earlier times communication could be carried on only by messenger or between fixed points by semaphore or heliograph. The advance in communication has been essentially by electrical means. As early as 1746 Watson transmitted electric signals through 10,000 ft of wire using an earth return. In 1833 Morse developed a means of recording signals on a paper tape by the operation of an electromagnetically operated pencil, and in 1838 introduced the Morse Code system of signaling by a single needle which could be read by eye or ear.

The next development of importance was the invention of the telephone by Bell in 1876. As a receiver his principle is still in use, but various other forms of transmitter have been developed since, notably Edison's carbon transmitter. The work of Bell opened up a new field of communication which was developed very rapidly in the States and eventually all over the world. Notable improvements have been made in the quality of transmission due to the introduction of inductive loading of the lines based on the mathematical researches of Heaviside and first put into practical operation by Pupin.

The development of wireless communication based on Maxwell's mathematical researches developed experimentally by Hertz, Helmholtz, Righi, and Marconi led to the practical transmission of wireless signals, over short distances. In 1901 Marconi succeeded in transmitting across the Atlantic in Morse Code the letter "S," and from that time onward wireless telegraphy was developed rapidly. The whole trend of wireless communication changed with the practical development of the Edison effect in the production of the thermionic valve which gave a means of generating current at any frequency and constant amplitude, and a means of amplifying signal voltages however faint. Through these means, wireless telephony—the first successful experiments in which, employing the Poulsen arc, had been made in 1908—came into general use and was developed rapidly.

A further phase of communication is that relating to the transmission of pictures both by wire and wireless methods. These now have reached a stage of considerable development as will be appreciated from the examples seen in the daily press. Arising out of wireless developments has come the modern amenity, broadcasting. This took practical form in the United States in 1921 and its remarkable development throughout the world is one of the romances of the Century. The future holds the possibilities of television which has already, under special conditions, been brought to a fair degree of perfection, but in as far as general application is concerned, is still in an incomplete state of development.

The advances that have been achieved within the Century in communication while associated with outstanding names such as Morse, Wheatstone, Hughes, Bell, Edison, Kelvin, Marconi, De Forrest, Poulsen and others, have been supplemented by a vast army of brilliant scientific and technical workers whose labors have made the amenities of modern communication possible in so short a space of time.

One of the greatest amenities developed during the Century has been illumination, revolutionized by the development of the carbon filament lamp by Edison and Swan. A landmark in electric lighting by this new illuminant was seen at the World's Fair at Chicago in 1893. A great step forward in the efficiency of electric lamps was made possible by the discovery by Dr. Coolidge of the method of producing ductile tungsten, leading to improvements on the early drawn-wire filament lamps. The further advance, due to Dr. Langmuir, of the use of an inert gas and the close coiled filament increased the filament life by reducing the rate of its evaporation. In parallel with these developments has been the work of Claude and others on high voltage low discharge tubes employing neon and other gases for color effects.

It has long been appreciated that a source of illumination depending on the incandescence of a solid body must be an inefficient means of converting electrical energy into visible radiation, and increasing attention is being directed to glow discharge depending on the radiation from the atom. In this field, work has been done by many researchers, employing cold cathodes and high voltages, but more success has been attained by the introduction of hot cathodes and employing a mixture of metallic vapor and a permanent gas. Under laboratory conditions an efficiency with this form of illuminant of 360 lumens

per watt has been obtained as compared with 3.5 lumens per watt with a carbon filament lamp or 12.9 with a tungsten gas filled 100-watt lamp. In spite of very high efficiency, vapor lamps suffer from the drawback that they do not give a continuous spectrum which, however, is a defect that time may overcome. In street lighting and in many other applications, these limitations are not vital and are outweighed by increased efficiency.

In the direction of the preservation of food it is no exaggeration to say that no scientific advance since the advent of railways and steamboats has so greatly altered the economic life of Europe and America as has refrigeration and canning, without which it would be impossible to maintain an adequate food supply especially to the large concentrations of industrial populations in the towns and cities.

The outstanding use of electrical power in therapeutics has been that associated with the development of X-ray tubes. It is still too early to determine how far-reaching this application of electricity will be, but it offers great possibilities in the treatment of cancer. The use of electrical energy at high frequencies for diathermy treatment is now well known and has considerable application.

. . . .

Reviewing the use of power through the Century and bearing in mind that in 1833 the total amount of power in the world available for use was probably less than that represented by a single one of the largest units in a modern power plant, it is estimated that today the horsepower generated is of the order of 100 million kilowatts, and the total investment in electrical power supply alone throughout the world is of the order of 2,000 million dollars. A conservative estimate of the number of horsepower installed in nine countries for which there are reliable statistics is 148 million horsepower, and this represents only a fraction of what might be usefully employed throughout the world.

Contemporary Developments in Other Industries

Prior to 1833 the constructional metals employed in supplying the rapidly expanding demands of engineering developments were cast iron, wrought iron and steel made by the crucible process introduced by Huntsman in 1746. The most important metallurgical invention in the early part of the Century was the Bessemer process in 1856; the next great advance was the introduction in 1865–70 of the Siemens' acid open hearth process in England and the Martin Brothers similar process in France. In 1880 the development of the basic lined converter by Thomas and Gilchrist enabled the use of high phosphoric pig iron and gave a tremendous impetus to ferrous metallurgy in Germany. Since 1880 steel making processes have not materially altered.

The development and heat treatment of alloy steels is the most important phase of modern steelmaking and has had far reaching consequences. The availability of such alloys has facilitated the economic production of modern motor cars, aero engines, and electric generators.

While the melting of metals by electric means occurred to Joule as early as 1855, electric furnaces, even on a small scale, did not come into use until about 1879. The period since has seen the development of the arc, the resistance, the induction, and in recent years, the high frequency coreless induction furnace. Each has contributed to the development of metallurgy. In particular the high frequency furnace enables steel alloys to be produced economically and with a high degree of purity.

Progress in non-ferrous metallurgy has been in the direction of greater purity, and of alloying, in some cases with iron; the development and metallurgical treatment of the rare metals; and the commercial production and exploitation of metals of low specific gravity and their alloys. An outstanding development of new material is that of aluminium.

The Century's progress in chemical developments has been marked by the growth of the synthetic organic chemical industry which depended for its development on the supply of coal tar, which followed from Murdock's discovery and the commercial exploitation between 1792–1813 of the production of illuminating gas from the distillation of coal. The heavy chemical industries received impetus from the cheap production of sodium carbonate by the Leblanc process, thereby giving great benefit to the soap, textile, and glass industries. It is remarkable how much the world owes today to synthetic chemistry which provides dyes, drugs, oils, perfumes, explosives, fabrics, resins, and other products, as well as having an enormous influence on the food, textile, mining, and other industries.

Research

At the commencement of the century there were many notable men of science conducting research in various fields, the results of which were to find application in different industries. Most industries were in an embryo stage of development and their progress depended on the growing experience of the workers engaged in them, enhanced by the inspiration of men of genius and of inventors who from time to time contributed to progress. About 30 years ago progressive firms began to undertake the solution of their every-day problems on more scientific lines and gradually this service developed into an organized effort to advance the knowledge of the art and thereby advance progress. This was the beginning of what we now understand as industrial research.

A further step has been the coördination of these private research activities with those of the university or state associations to bring about in the different countries national research organizations. In America, the National Research Council functions in this manner; in Germany, the Kaiser Wilhelm Institute; in Great Britain, the government's Department of Scientific & Industrial Research; in Japan, the National Institute of Physical & Chemical Research and others; in the U.S.S.R. research of a fundamental character and that of the main industries is coördinated through a state department.

While there are names of international reputation

identified with research, one must not overlook the fact that in every country there are today scattered in the laboratories of universities, in national laboratories, in private commercial laboratories, and in research laboratories of industrial concerns, thousands of research workers, highly trained in their own field of activity, to whom much of the modern rate of progress in industry is due.

1933

Reviewing the past 100 years of development in industry and engineering, certain considerations are outstanding. First, engineering is the basis on which the magnitude and rate of progress depends. Through the growth and application of scientific knowledge it has made the world a small place; it has increased speed of travel by road, rail, air, and water; through speed of communication, it has eliminated time and distance; it has enabled the earth's resources to be made universally available; it has been the means of providing for the growth and maintenance of populations with increasing standards of living. In other directions, medical science and its universal availability has made enormous strides, not only in the cure of disease but in disease prevention and in improved hygienic standards. Similarly there has been an extension of the availability of all grades and phases of education.

The wealthiest of the community 100 years ago had only a fraction of the amenities so widely enjoyed today. Hours and arduousness of labor have steadily diminished and provided the leisure for cultural pursuits, physical recreation, and amusements.

It is sometimes said that human nature cannot control the machines that science and invention have produced, and that this is largely responsible for the present state of world derangement. It is true that due to the creative impulse of war, facilities for production attained a century's advance within a few years and that exchange and distribution did not keep pace with this abnormal growth, but surely this is a problem of organization only, and should not be beyond human intelligence to solve. Moreover, there are certain features in the trend of affairs that should be cause for confidence. The early part of the Century, in fact the greater part of it, saw a rapid development of wealth and its acquisition by comparatively few people; the material progress of the community seemed to matter most. Today, there is a tendency, which the economic stress has served to emphasize, to regard industry as a service as a means to an end; the end being the greater development of intellectual life and higher ethical standards. It is surely the responsibility of us, who are engineers, scientists, and industrialists, to foster this spirit.

A Single-Unit High-Current Rectifier

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Research on mercury arc rectifiers indicates that up to a certain temperature the arc drop is reduced as the temperature is raised, and that the efficiency is increased accordingly. These facts have been applied to the design of single-unit 3,000-kw 625-volt rectifiers, some of which are now in use on the Eighth Avenue subway in New York City. The provision of control grids makes the rectifier applicable to a wide variety of uses.

A HIGH-CURRENT mercury arc rectifier in single-unit form is one of the recent developments in conversion apparatus. A reliable unit with a nominal rating of 3,000 kw at 625 volts and having overload ratings up to 300 per cent full-load current has been made available for commercial applications. Some of these units are now in operation on the new Eighth Avenue subway in New York City. Others are installed on railway systems and in electrolytic plants. This size and type of unit first was developed to fill traction system requirements for a compact and reliable power unit having high overload capacity. However, it is expected to find a wide variety of industrial applications because of its high overall load efficiency, quietness of operation, adaptability to grid control, and other desirable characteristics.

Many of the advantages of mercury arc rectifiers have been realized in their application to the power system of the New York City Board of Transportation subways. Their use has made possible the location of the substations underground and adjacent to

Essentially full text of "A Recent Development in High-Current Mercury Arc Rectifiers" (No. 33-13) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

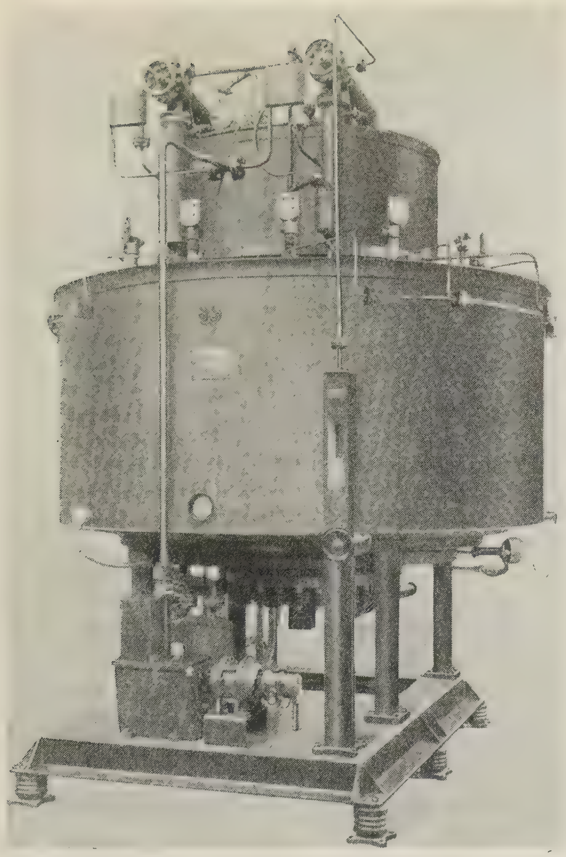

Fig. 1. Front view of 3,000-kw 625-volt single-unit mercury arc rectifier

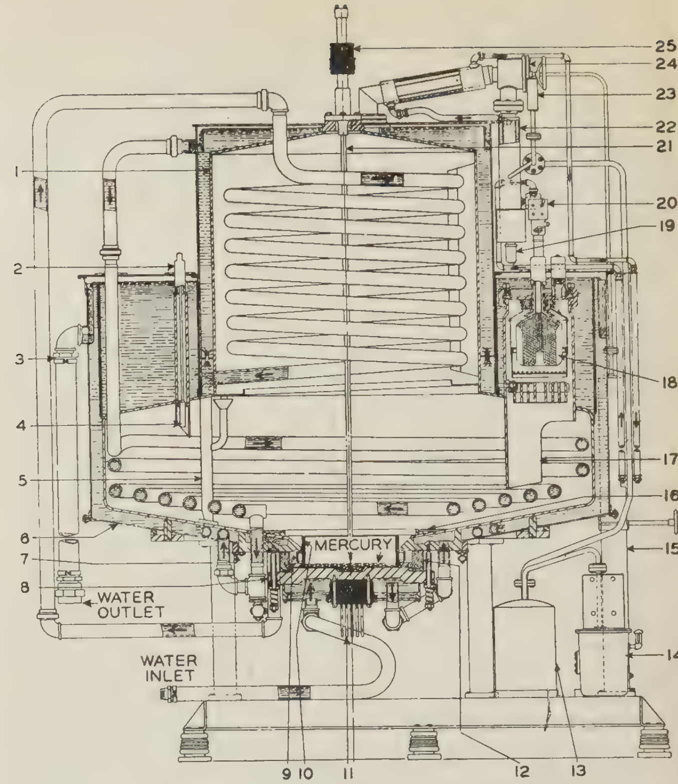

Fig. 2. Cross-sectional view of 3,000-kw 625-volt rectifier

1. Vacuum chamber
2. Excitation anode seal
3. Overflow graphite nipple
4. Excitation anode tip
5. Mercury drain strut
6. Tank water jacket
7. Tie ring
8. Cathode
9. Cathode outer shield
10. Cathode inner shield
11. Cathode stud
12. Cathode insulator
13. Gas receiver tank
14. Rotary vacuum pump
15. Vacuum gage
16. Trash rack
17. Main anode shield
18. Main anode tip
19. Mercury condensation pump heater
20. Main anode terminal
21. Ignition anode rod
22. Mercury condensation pump
23. Mercury trap
24. Accordion vacuum valve
25. Ignition anode coil

the subway tracks. A considerable saving was effected by this arrangement as the substations could be located under city streets thus obviating the purchase of valuable property for substation sites. These substations consist of a single room built of reenforced concrete and containing the transformers, switchgear and all other equipment required in connection with the operation and control of the rectifier. A simpler, more compact, and less expensive substation construction is obtained by the use of rectifiers instead of synchronous converters. Heavy foundations are not necessary as the rectifier has no rotating parts and is comparatively light in weight. Also since water can be used for cooling, no expensive duct system and ventilating equipment are required. Furthermore, with rectifiers the fire hazard is reduced, and the noise problem eliminated. Altogether, the rectifier forms an ideal conversion unit for underground installation.

Design of the high-current rectifier is based upon principles evolved by intensive investigation and research. Some of these principles have been outlined in a paper "Mercury Arc Rectifier Research" by A. W. Hull and H. D. Brown (A.I.E.E. Trans., v. 50, 1931, p. 744–56). Further tests have been made to determine the limiting values of the various factors involved in a design for heavy currents. Data from these tests together with data obtained from the various sizes of rectifiers operating successfully in the field were used in arriving at the new design.

The form of the 3,000-kw tank is similar to that of previous rectifiers except for changes required by the greatly increased rating. The rating of a rectifier may be increased by raising its operating voltage without changing greatly its overall dimensions. The design of a high-voltage rectifier is mostly a matter of general placement, spacing, and insulation of the various parts. Increasing the current rating, however, involves the enlargement of the tank and its parts. The size of a rectifier is determined chiefly by its current rating, the losses in a mercury arc being almost directly proportional to the load current. This means that for increased current capacity the condensing area must be greater and the current carrying parts must be enlarged. In making these changes care must be taken to provide an arc path of the proper dimensions between anode and cathode. If the arc stream is greatly lengthened or the arc area is made too small the arc loss will be increased and part of the advantage of the larger unit will be lost.

A cross-sectional view showing the arrangement of internal parts in the rectifier supplied for the New York City Board of Transportation may be seen in Fig. 2. The vacuum chamber, consisting of the lower tank and the dome, constitutes the greater part

of the effective condensing area. The water coils in the lower section and in the dome form about $^1/_3$ of the total effective condensing area. Ample cooling area has been provided to maintain effective control of the vapor pressure at all loads. Cooling coils afford a very inexpensive way of increasing the cooling area and the overload capacity of the rectifier. A rectifier vacuum chamber having the same condensing area without cooling coils would be much larger in size and would have greater spacing between electrodes.

Current carrying capacity of a given rectifier is determined among other things by the mercury vapor pressure (or, practically speaking, the operating temperature) and the cross-sectional area of the anode arms. By furnishing proper baffling surfaces and dividing the arc into small streams, reliable operation can be obtained at higher temperatures. When the rectifier is so baffled, the maximum current that can be carried increases uniformly with increase in temperature, within a certain temperature range, and is directly proportional to the cross-sectional area of the anode arms. The cross-sectional area of the anode arms is fixed largely by the maximum desired overload rating of the rectifier. Sufficient arc section must be provided to carry the peak anode currents without excessive arc drop.

As the temperature is increased, up to a certain value, the arc drop is lowered. In this rectifier full advantage has been taken of this factor, as can be seen from the curve shown in Fig. 3. This curve was obtained by taking arc drop readings on a rectifier as its operating temperature gradually was raised, the current being maintained constant at normal load value. This test shows that the rectifier operates at maximum efficiency between 70 and 80 deg C, and indicates that at this temperature it should carry its largest overloads. A high operating temperature is desirable from another standpoint, that of cooling efficiency. A reduction in cooling water consumption to from $^1/_3$ to $^1/_2$ of that required by other designs has been made possible by the increased operating temperature.

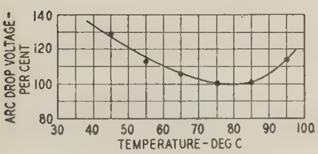

Fig. 3. Variation in arc voltage with operating temperature in a rectifier carrying normal load

Arc drop expressed in per cent of normal arc drop at full load and normal operating temperature

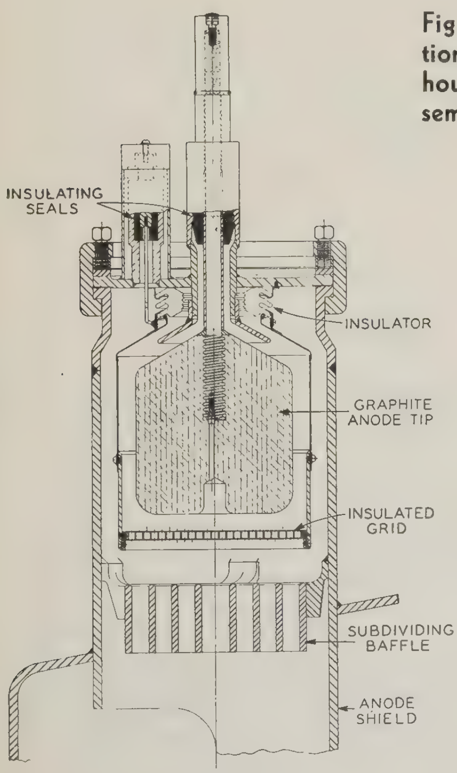

Fig. 4. Vertical sectional view of anode housing and anode assembly of rectifier shown in Fig. 2

Control Grid Provided

A cross-sectional view of the anode assembly is shown in Fig. 4. The anode tip, which is of graphite, is supported from the vacuum chamber by means of an insulating "mycalex" seal. It is surrounded by an insulated shield which supports the grid. The grid, which also is of graphite, is placed in front of the anode so that the arc must pass through it to reach the anode; it consists of a flat disk perforated with small holes closely spaced in order to utilize a large portion of the total area for the passage of the arc. An insulated lead is brought out from the grid through a small "mycalex" seal so that a separate potential may be applied to the grid. Below the anode and grid is a subdividing baffle, which consists of several concentric steel rings supported from arms welded to the walls of the anode housing.

An improvement in high-current rectifiers has been obtained by the addition of a trash rack. This is installed in the vacuum chamber just above the cathode so that the condensed mercury must pass through it when returning to the cathode. It serves 2 purposes: First, it collects all dirt and foreign matter floating on the returning mercury, thereby gradually cleaning the vacuum chamber and preventing contamination of the mercury in the cathode; second, by means of small holes or weirs it distributes the returning mercury so that it will not flow in one large stream which might produce a short circuit between the vacuum tank and the cathode. The importance of the second factor will be seen when the amount of mercury circulated in the tank is considered. At 300 per cent load the rate of vaporization of mercury from the cathode is approximately 14 lb per minute. In addition to the trash rack a system of troughs and pipes is provided to catch the mercury

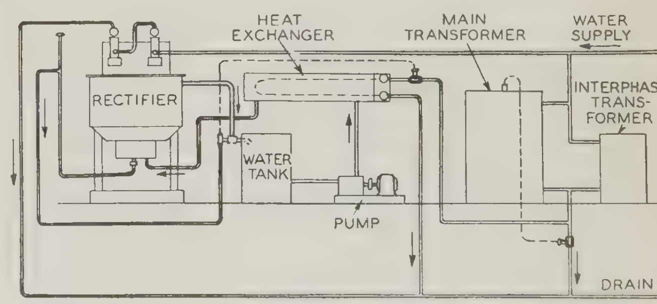

Fig. 5 (right). Schematic diagram of closed cooling system used with rectifiers on New York City Board of Transportation system

condensed in the dome and return it to the cathode, thus lessening the possibility of splashing.

The rectifier is designed for a-c ignition and excitation. A single plunging anode is used for ignition, and 3 small graphite anodes for the excitation arc. The insulated grids are excited with a d-c bias in order to supplement the holding anode excitation and aid pick-up. The exhaust system consists of 2 mercury condensation pumps operating in parallel and connected to one rotary oil roughing pump. Exhaust is from the dome where the foreign gas tends to collect under the combined action of the arc and condensing mercury. Vacuum is measured by a McLeod gage in one exhaust line and a hot wire manometer gage in the other.

Recirculating Cooling System

Several novel features are incorporated in the cooling system used on the New York City Board of Transportation rectifiers (see Fig. 5). It is a recirculating system with a water-to-water heat exchanger. The rectifier cooling water is circulated continuously by a centrifugal pump. The heat imparted to the cooling water while flowing through the rectifier is carried away by the tap water flowing through the heat exchanger. The high operating temperature of the rectifier has made it possible to connect the transformer and rectifier tap water systems in series, the water flowing through the transformer cooling coils first, then into the heat exchanger and finally discharging into the drain. A further saving in cooling water is obtained by this arrangement. The flow of water is regulated by 2 temperature controlled valves, one of which is actuated by the rectifier temperature, the other by the transformer temperature. The valve controlling the flow of water through the heat exchanger is actuated by a bleeder circuit connected to the rectifier at the point of most rapid temperature fluctuation. Accurate control of temperature at all loads is secured by this system. At light load no cooling water is required by the rectifier so its valve closes. The valve actuated from the transformer then opens a bypass into the drain permitting water to flow through the transformer alone.

The use of a heat exchanger with a recirculating system permits the discharge into the drain to be located at a higher level without applying pressure to the rectifier. This is desirable where the rectifier is installed in an underground substation. By means of the circulating pump a large flow of water can be obtained at all loads, providing efficient cooling and assuring uniform temperature. The closed system permits ready treatment of the cooling water for prevention of corrosion.

The 3,000-kw units installed on the New York City Board of Transportation system are arranged to operate as simple rectifiers with 5 per cent shunt regulation. Each rectifier is connected to a 12-phase zig-zag-connected power transformer with an interphase transformer. Straight rectification is only one of the many possible applications of this high-current unit. By proper excitation of the control grids which have a control ratio of power controlled to control power of almost 100,000 to 1, the unit can be used for such applications as: voltage regulated d-c power output, high-speed circuit breaker, inverter, and static frequency changer.

Operation of rectifiers of this size to date has demonstrated their reliability and the soundness of their design. Experience for several years with the construction and operation of both single and multiple units indicates that the single unit possesses some advantages. With the single unit the number of auxiliaries can be reduced to a minimum. This is highly desirable as the auxiliaries play a large part in determining the overall reliability and maintenance on a rectifier installation. The construction of a successful single-unit rectifier has been made possible only by the development of a vacuum tank having component parts possessing a high degree of reliability. Such reliability is now obtainable by the use of sturdy insulating seals, improved welding, indestructible graphite parts, proper placement of parts, and latest manufacturing technique. These factors have contributed largely to the success of the high-current single-unit rectifier.

Incremental Loading of Generating Stations

Transmission line losses are taken into account in the method of determining loading of generating stations for maximum overall economy as outlined in this article. The material, although not entirely new, is presented so as to be useful to power system operators.

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ECONOMICAL division of load between 2 or more generating stations, when the transmission line losses are negligible, becomes merely a problem of operating the stations at loads which correspond to the same incremental rate. By incremental rate of a station is meant the slope of the

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curve, the ordinates, and abscissas of which are, respectively, the heat input and the output of the station; if the heat input is expressed in British thermal units per hour and the output is expressed in kilowatts, the incremental rate will be expressed in British thermal units per hour per kilowatt. An incremental rate curve may be obtained for any station from an overall efficiency curve of the station by plotting the slope of the efficiency curve expressed in British thermal units per hour for various values of kilowatt load.

When the line losses are appreciable, the load division procedure must be modified to take them into account. The principles involved can be understood more readily by considering the simplest case, that of 2 interconnected generating stations.

Two Generating Stations

In order that it be economical to transfer a given load from one station to another, the following relation must prevail:

$$R_S = R_R \times E_{IT} \quad (1)$$

where

R_S = incremental rate of the sending station corresponding to the load G_S generated by the sending station

R_R = incremental rate of the receiving station corresponding to the load G_R generated by the receiving station

E_{IT} = incremental efficiency of the transmission line corresponding to the given load transferred

The incremental efficiency must not be confused with the absolute efficiency of the line. The latter is merely the ratio of the load at the receiving end to the load at the sending end. The incremental efficiency is the slope of the curve whose ordinates and abscissas are, respectively, the load T_R at receiving end of the line, and the load T_S at the sending end of the line.

Table I—Sample Calculation Showing Method of Adjusting Incremental Heat Rates of Station A for Tie Line Loads

Tie Line Load (T_A)	Demand in Area Served by Station (D_A)	Net Load Generated (G_A)	Actual Station Incremental Rate (R_A) Btu/Hr/Kw	Tie Line Incremental Efficiency (E_{IT})	Adjusted Station Incremental Rate (R'_A) Btu/Hr/Kw
+100	400	500	16,000	0.800	20,000
+ 80	400	480	15,230	0.840	18.130
+ 60	400	460	14,710	0.880	16,720
+ 40	400	440	14,280	0.920	15,520
+ 20	400	420	13,880	0.960	14,460
0	400	400	13,500	1.000	13,500
− 20	400	380	13,150	0.958	12,600
− 40	400	360	12,830	0.916	11,750
− 60	400	340	12.530	0.871	10,910
− 80	400	320	12,270	0.825	10,120
− 90	400	310	12,160	0.800	9,730

When T_A is +, tie line feeds out. $R'_A = R_A \times \frac{1}{E_{IT}}$.

When T_A is −, tie line feeds in. $R'_A = R_A \times E_{IT}$.

All loads in megawatts.

In computing the incremental line efficiency it is necessary to consider only the losses due to the load component of the line current, disregarding the line charging component.

Corresponding to eq 1, a second equation may be written as follows:

$$R_R = R_S \times \frac{1}{E_{IT}} \quad (2)$$

Analysis of eqs 1 and 2 indicates that when 2 stations are interconnected, the incremental rates of either one must be multiplied by a factor to compensate for the line losses. If the station whose incremental rates are to be adjusted is receiving power, the correction is made by multiplying its rates by the incremental efficiency corresponding to the load on the line; if the station is transmitting power, its rates are divided by the incremental efficiency.

Table II—Sample Calculation Showing Derivation of Combined Incremental Heat Rates for Stations A and B

Incremental Heat Rate* Btu/Hr/Kw	Net Loads Generated: Station A (G_A)	Net Loads Generated: Station B (G_B)	Demand in Area Served by Station A (D_A)	Tie Line Load (T_A)	Tie Line Losses (L_A)	Total Load Generated ($G_A + G_B$)	Total Demand ($D_A + D_B$)
20,000	500	500	400	+100	10.0	1,000	990.0
19,500	496	500	400	+ 96	9.2	996	986.8
19,000	490	500	400	+ 90	8.1	990	981.9
18,500	484	482	400	+ 84	7.1	966	958.9
18,000	478	463	400	+ 78	6.1	941	934.9
17,500	472	442	400	+ 72	5.2	914	908.8
17,000	464	419	400	+ 64	4.1	883	878.9
16,500	457	395	400	+ 57	3.3	852	848.7
16,000	448	368	400	+ 48	2.3	816	813.7
15,500	440	339	400	+ 40	1.6	779	777.4
15,000	430	309	400	+ 30	0.9	739	738.2
14,500	420	277	400	+ 20	0.4	697	696.6
14,000	410	242	400	+ 10	0.1	652	651.9
13,500	400	207	400	0	0	607	607.0
13,000	389	169	400	− 11	0.1	558	557.9
12,500	378	128	400	− 22	0.5	506	505.5
12,000	366	87	400	− 34	1.2	453	451.8
11,500	354	44	400	− 46	2.3	398	395.7

* Adjusted values for station A (R'_A).

Actual values for station B (R_B).

$D_A + D_B = G_A + G_B - L_A$.

Tie line feeding out, T_A is +.

Tie line feeding in, T_A is −.

All loads in megawatts.

Although eqs 1 and 2 define the conditions that must prevail for economical transfer of power between 2 generating stations, they do not by themselves indicate the economical load division for a given demand. A direct solution of the problem is made possible by the computation and use of incremental rate curves which have been adjusted in accordance with eqs 1 and 2. To illustrate, consider 2 generating stations A and B with incremental heat rate curves shown in Fig. 1. The stations are interconnected by a transmission line, the losses and incremental efficiencies of which are shown in Figs. 2 and 3, respectively.

The actual incremental heat rates of station A as shown in Fig. 1 were adjusted for various values of load transferred between stations and for various loads in the area normally supplied by station A, giving an equivalent rate in terms of the other station and making possible a graphical comparison of the 2 station rates. The adjustments were made by using eqs 1 and 2; a sample calculation for one curve is shown in Table I, which is worked out for the case

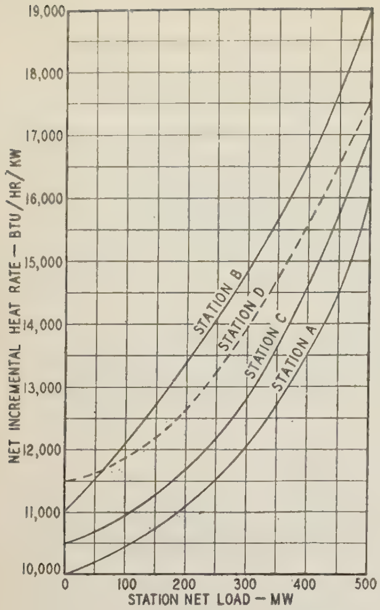

Fig. 1. Actual station incremental heat rate curves

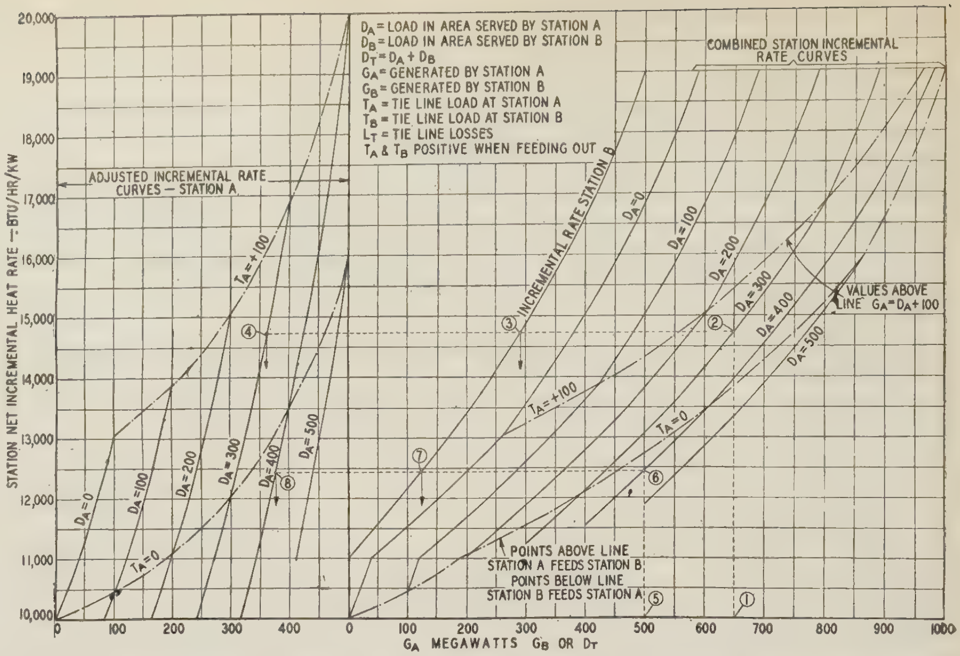

Fig. 4. Determination of station and tie line loading for maximum overall efficiency, assuming 2 generating stations. See Table III for examples shown

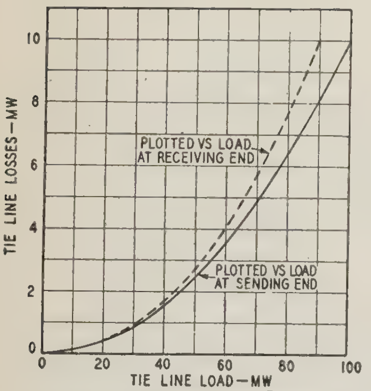

Fig. 2. Tie line losses

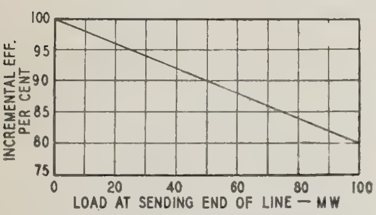

Fig. 3. Tie line incremental efficiency

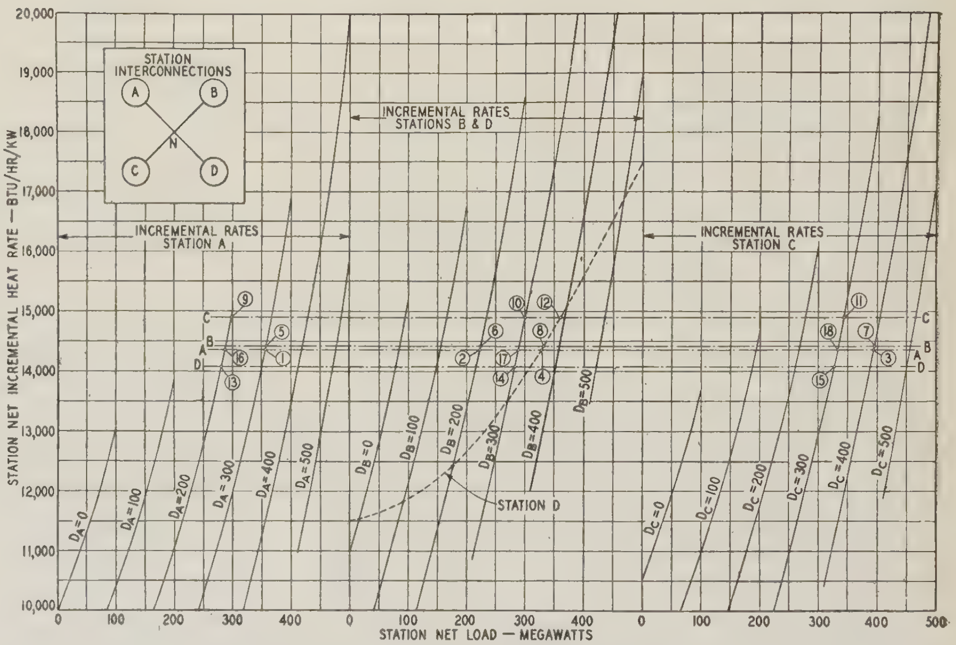

Fig. 5. Curves to determine load division among 4 interconnected generating stations for maximum overall economy

of a demand of 400 megawatts in the area served by station A and for various tie line loads; this computation appears as the curve marked $D_A = 400$ on the left-hand side of Fig. 4. The other curves on the left-hand side of Fig. 4 were obtained in a similar manner. On the same diagram with the adjusted incremental rates for station A is plotted the actual incremental rate of Station B. Also, the combined incremental rate curves for various values of load in the area served by station A were computed and plotted against the combined load in both areas; allowance for tie line losses was made in these calculations. The manner of computing the combined curve is shown by the sample calculation of Table II, which is worked out for the case of a demand of 400 megawatts in the area served by station A, and for various incremental heat rates; this computation appears as curve $D_A = 400$ on the right-hand side of Fig. 4. Similar computations were made for the other curves. The curve for $T_A = 100$ and $T_A = 0$, which appear on both sides of this diagram are obviously the difference between the generation of station A and the demand of the area served by that station.

Curves similar to those in Fig. 4 may be drawn for any 2 stations connected by a transmission line

and may be used to determine easily the station and tie line loading for maximum overall efficiency. Two examples worked out to illustrate the use of the curve are shown in this figure; the conditions upon which these examples are based are given in Table III. In example 1, the diagram is entered at point 1. At point 2 the incremental rate is indicated, the value of which corresponds both to the adjusted value for station A and the actual value for station B. The intersections of the curves of stations B and A at points 3 and 4, respectively, with this incremental rate value, determine the loads that should be generated by the respective stations.

Similarly, for example 2, the diagram of Fig. 4 is entered at point 5 and the respective station loads determined at points 7 and 8.

Table III—Data for Examples Shown on Fig. 4

	Example No. 1		Example No. 2	
D_T		650		500
D_A		300		400
D_B		350		100
G_B		292		124
G_A		362		377
T_A	[362-300]	+62	[400-377]	−23
T_B	[350-292]	−58	[124-100]	+24
L_T	[62-58]	4	[24-23]	1

Table IV—Example 3 Illustrating the Use of Curves of Fig. 5

Station	Demand in Area Served by Station (1)	Step 1: Net Load Generated (2)	Step 1: Tie Line Load (3)	Step 1: Tie Line Losses (4)	Step 2: Net Load Generated (5)	Step 2: Tie Line Load (6)	Step 2: Tie Line Losses (7)
A	300	355	+55	3.1	357	+57	3.3
B	200	222	+22	0.5	224	+24	0.6
C	400	395	− 5	0	396	− 4	0
D	400	328	−72	5.2	332	−68	5.4
Totals	1,300	1,300		8.8	1,309		9.3

Column (1) The demands in the areas served are known.

(2) The total demand is divided neglecting line losses. The station loads are obtained from points 1 to 4, inclusive, on line A-A. The position of line A-A is determined by cut and try method so that the sum of the station loads equals 1,300.

(3) The tie line loads are approximate. Positive flow is toward the common point N.

(4) The line losses are obtained from Fig. 2, using only the solid curve since the values are approximate.

(5) The station loads are determined from points 5 to 8, inclusive, on line B-B, the position of which is determined by cut and try methods so that the sum of the station loads equals 1,309.

(6) Revised tie line loads.

(7) Tie line losses corresponding to revised tie line loads. Both line loss curves of Fig. 2 are used.

All loads in megawatts.

Three or More Generating Stations

When the interconnection consists of more than 2 stations, an exact solution requires the computation of a very large number of curves involving a prohibitive amount of labor. An approximate method, however, may be used giving results in very close agreement with those obtained by an exact solution. Briefly the method involves 3 steps:

1. Determination of the load division neglecting line losses.
2. Approximation of the line losses.
3. Redivision of the load increased by the approximate line losses.

Application of this method to a hypothetical interconnection consisting of 4 stations is illustrated by the curves of Fig. 5, and their use by Tables IV and V. For the sake of simplicity, the stations were assumed to be of equal capacity, and interconnected as shown in Fig. 5. The sections of tie line, between bus and the common point N, were assumed to have identical performance characteristics. The performance data for the stations and tie lines used for illustrative purposes are shown in Figs. 1, 2, and 3.

In Table IV the final load division corresponds to a total demand of 1,299.7 megawatts compared with the actual demand of 1,300 megawatts; in Table V the demand corresponding to the load division is 1,299.3 megawatts compared with 1,300 megawatts. In both cases, the differences are negligible for all practical purposes

Analysis of the results shown in Tables IV and V clearly indicates that the use of this approximate method will give results that are well within the accuracy of the metering facilities and the accuracy with which the performance curves of the generating stations can be established.

Table V—Example 4 Illustrating the Use of Curves of Fig. 5

Station	Demand in Area Served by Station (1)	Step 1: Net Load Generated (2)	Step 1: Tie Line Load (3)	Step 1: Tie Line Losses (4)	Step 2: Net Load Generated (5)	Step 2: Tie Line Load (6)	Step 2: Tie Line Losses (7)	Step 3: Net Load Generated (8)	Step 3: Tie Line Load (9)	Step 3: Tie Line Losses (10)
A	200	296	+ 96		280	+80	6.4	286	+86	7.4
B	300	300	0		282	−18	0.3	288	−12	0.2
C	300	344	+ 44		328	+28	0.8	334	+34	1.1
D	500	360	−140		410	−90	10.0	410	−90	10.0
Totals	1,300				1,300		17.5	1,318		18.7

Step 1. Procedure same as outlined in Table IV. Station loads determined from points 9 to 12, inclusive, on line C-C. Line losses not determined since overload is indicated on line from point N to station D.

Step 2. The minimum generation of station D to eliminate overloading the tie line is $500 - 90 = 410$ megawatts, since 90 megawatts is the maximum load that can be supplied to the station. Neglecting line losses, stations A, B, and C must generate $1{,}300 - 410 = 890$ megawatts. Points 13, 14, and 15 on line D-D indicate the 3 station loads totalling to 890 megawatts. Tie line loads and losses obtained as in Table IV.

Step 3. Procedure is the same as in step 2 of Table IV except that the load on station D is kept at 410 megawatts. Total generation by stations A, B, and C $1{,}318 - 410 = 908$ megawatts and respective station loads are indicated by points 16, 17, and 18 on curve A-A.

All loads in megawatts.

Impulse Tests on Distribution Transformers

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Impulse voltage tests emphasize the desirability of proper coördination between the winding and bushing insulations of electric power distribution transformers. "Surge proof" transformers should have a reasonable factor of safety between insulation puncture voltage and minimum bushing flashover voltage. These are some of the principal conclusions drawn from an investigation conducted recently at the high voltage laboratory of Purdue University.

SHALL a prospective purchaser of "surge-proof" transformers be content to depend upon either external or internal protective devices, or shall he insist upon certain specified factors of safety for the bushing flashover and the insulation puncture voltages above the protective gap flashover voltage? In an attempt to answer these questions a series of impulse voltage tests have been made on distribution transformers at the high voltage laboratory of Purdue University, Lafayette, Ind.; these tests were conducted with the coöperation of the Utilities Research Commission of Chicago, Ill. This investigation was the outcome of previous tests of a standard 2,300–4,000 to 115/230-volt distribution system, upon which both induced and direct-stroke surge potentials were impressed. (See "Distribution System Lightning Protection; Interconnection of Primary Arrester Ground and Secondary Neutral II—Tests on a Typical Urban Circuit," by C. F. Harding and C. S. Sprague, ELECTRICAL ENGINEERING, v. 51, Sept., 1932, p. 639–42.)

During the previous tests it was found that, with usual city conditions, consisting of a multiplicity of low resistance ground on the secondary neutral, and the further possibility in some instances of a lightning arrester ground of high resistance, the interconnection of the primary arrester ground and the grounded secondary neutral definitely limits transformer stresses to values which should reduce lightning failures to a practically negligible quantity, even on the older non-surge-proof types of transformers. During those tests it became evident, however, that certain changes in the design and construction of those transformers would cause them to be practically surge-proof. Subsequently, transformers of various designs were tested in the high voltage laboratory, as described in this article. These transformers withstood all of the exposures when provided with lightning arresters or equivalent internal protection; without such protection, however, or in the event of failure of such protective devices to operate, the surge flashover of bushings and the insulation puncture voltages of the different transformers differed widely and hence provide undetermined factors of safety. Herein lies the line of demarcation at the present time between the various types of distribution transformers of the so-called surge-proof design and construction.

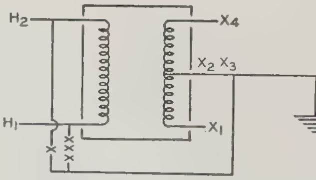
Based upon "Impulse Voltage Testing" (No. 33-51) presented at the A.I.E.E. winter convention, New York, N. Y., January 23–27, 1933.

Conclusions drawn from the results of the tests described here, are as follows:

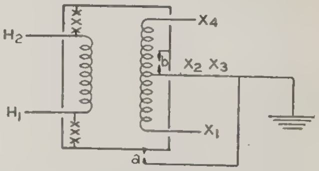
1. There should be a reasonable ratio between coil insulation puncture voltage, bushing flashover voltage on the inside of the transformer tank, and bushing flashover voltage outside of the tank.
2. Surge-proof transformers should have a reasonable factor of safety between insulation puncture strength and minimum bushing flashover values. Bushing flashover should occur outside the tank to assure, in case of failure of protective equipment, that the transformer insulation will not be damaged.
3. Conclusion 2 represents in general the ideal case. If extensive use of the interconnection of primary arrester ground and grounded secondary neutral results in reducing flashovers and punctures to a negligible number with non-surge-proof transformers, the added cost of the surge-proof type may be warranted only for special installations.
4. In making surge tests on transformers, the natural exposures will be most closely duplicated if surges are impressed between primary phase lead and grounded secondary neutral.
5. It seems likely that the insulation of transformer coils may be punctured by an impulse voltage and at a later time withstand line voltage.

TESTS ON PROTECTED TRANSFORMERS

The first tests consisted of impressing surges upon each transformer between primary lead H_1 and secondary neutral X_2X_3, as indicated in Figs. 1 and 2. In these tests the case was ungrounded and the primary phase and neutral arresters were connected between the respective primary terminals and the



Transformer protected by external arresters
XXX phase arrester
X neutral arrester



Transformer protected by internal arresters or gaps; arresters connected to secondary neutral when gaps a and b are not supplied

Figs. 1 (left) and 2 (right). Circuit diagrams for surge tests on distribution transformers; surge applied at H_1

grounded secondary neutral. This connection is equivalent to employing, in service, the interconnection of the secondary neutral and the primary lightning arrester ground.

As shown in Fig. 3 the applied test wave had a peak of 182 kv with the potential increasing at an average rate of 50 kv per microsecond on the major part of the wave front. This wave was adopted by the committee of the Utilities Research Commission in charge of the project as being more representative of the wave that was likely to reach the average distribution transformer than the steeper waves. Also, since the transformers were to be tested with arrester protection, this wave more nearly approximates the specifications for lightning arrester testing.

With arrester protection as described, the data of Table I and oscillograms in Figs. 4 to 6 were taken. The oscillogram of Fig. 5 indicates the potential between the primary neutral and the secondary neutral of transformers Nos. 1 and 4 with the primary neutral arrester connected, but evidently not operating. Another oscillogram obtained without the neutral arrester connection, indicated by its similarity to Fig. 5 that the neutral arrester had not operated in the former test. Fig. 6 illustrates how the potential of the ungrounded transformer case follows closely the potential of the secondary neutral. For one of the transformers with internal protection, and with the primary arrester discharging into the case, Fig. 7 shows that the potential of the case follows closely that of the secondary neutral until the primary arrester breaks down; at that time the potential between the case and the secondary neutral rises to the breakdown value of the coördinating gap between case and ground.

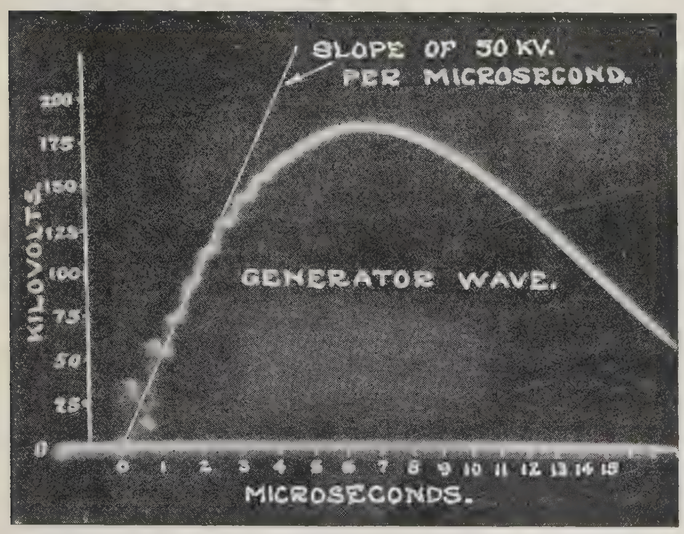


Fig. 3. Impulse generator wave

From Table I, it may be noted that the external lightning arrester connected between the primary phase and the secondary neutral limits the voltage across the transformer to about 19 kv. In transformer No. 6 with inclosed arresters the maximum voltage was 53.8 kv. While this illustrates the beneficial effect of the interconnection, obviously the transformer insulation was not subjected to a very severe test.

Voltages measured between the primary phase lead and the case, and between the case and the secondary neutral indicate that the ungrounded case assumes a potential close to that of the secondary winding. In transformer No. 6, however, the inclosed arresters discharge into the case and raise the potential between the case and the secondary to that determined by the breakdown of the case-to-ground, or the case-to-secondary-neutral gap, depending upon which gap is allowed to sparkover. The surge breakdown of the case-to-ground gap was found to be 22.8 kv; that of the case-to-neutral gap, 31.4 kv. For Transformer No. 6 the reading from the primary phase lead to the case gives the maximum arrester potential, in this instance 35.6 kv.

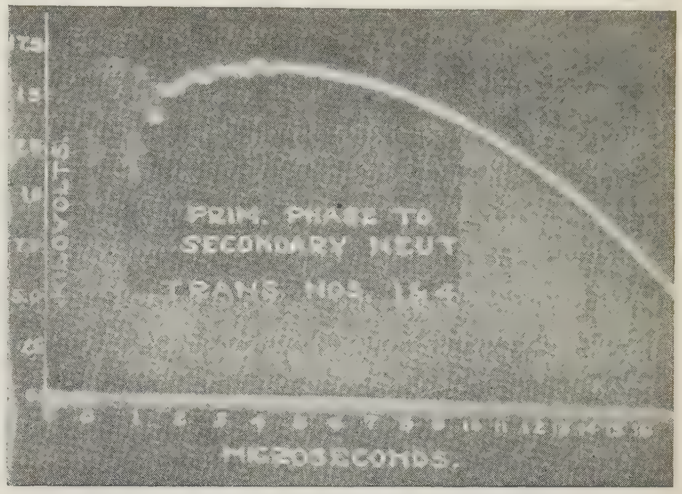


Fig. 4. Primary phase lead to secondary neutral

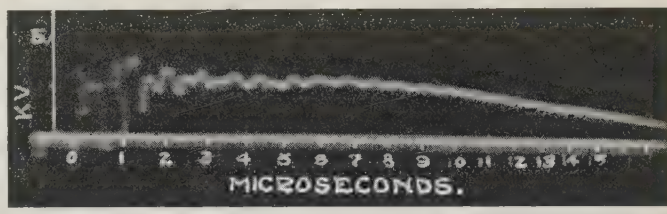


Fig. 5. Primary neutral to secondary neutral, with neutral arrester

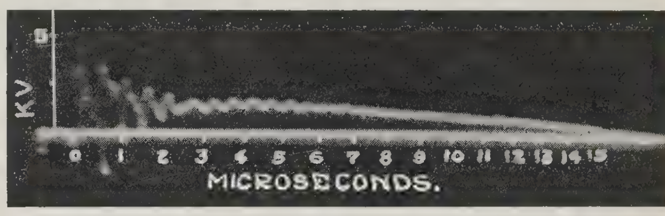


Fig. 6. Secondary neutral to transformer case

Figs. 4, 5, and 6. Surge potentials on transformers (Nos. 1 and 4) with external arrester protection

Voltages between the primary neutral and the secondary neutral were in some cases not sufficient to operate the 300-volt primary neutral arrester. With the primary neutral arrester removed, trans-

formers Nos. 2 and 3 showed a voltage between the primary neutral and the secondary neutral somewhat higher than that between the primary phase lead and the secondary neutral. This seems to indicate that the primary windings of these transformers had broken down between turns or layers. Reconnection of the neutral arrester reduced the voltage on the primary neutral to about 8 kv indicating that this

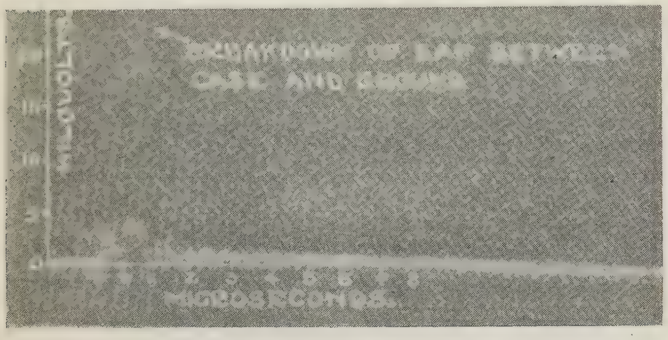


Fig. 7. Potential between transformer case and secondary neutral for transformer No. 6 with internal arresters discharging into the case

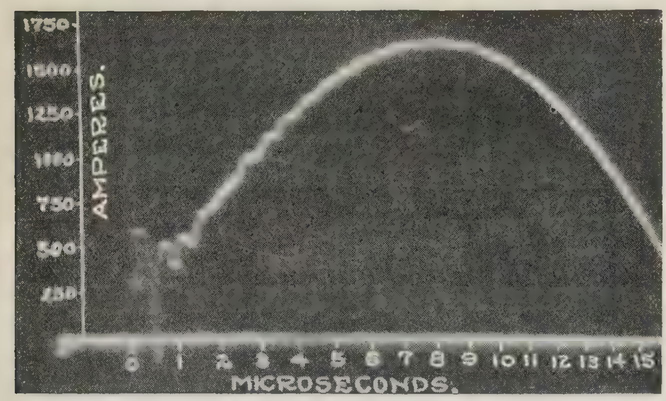


Fig. 8. Arrester surge current

value was the surge breakdown of these arresters. Oscillograms of Fig. 9 illustrate the potentials between the primary neutral and the secondary neutral with and without primary neutral arrester connected as in Fig. 1. It may be noted here that transformers Nos. 2 and 3 had indicated breakdown in direct stroke tests on an experimental distribution line. It was noted also in the laboratory surge tests on these 2 transformers, that when measuring the voltage between the primary phase lead and the case, a heavy discharge was obtained across the measuring gap, indicating the probable breakdown between the case and the grounded secondary.

It was not considered feasible to energize the transformers when tested on the line. However, in tests where the insulation between turns or layers may be punctured, the transformer may be energized as a means of detecting this type of breakdown which might not be apparent otherwise.

Two of the older transformers, Nos. 8 and 9, not of the surge-proof type, were tested; they showed no evidence of damage with arrester protection. The arresters were removed and the voltage increased until bushing flashover occurred at approximately 85 kv as noted in Table I.

Tests on Unprotected Transformers

In addition to the surge tests of the transformers with protection, 4 transformers were tested without protection up to the point of insulation failure. As before the surge was applied between the pri ary phase lead and the secondary neutral lead. A $\frac{1}{2}\times 10$-μsec wave was used, the peak voltage of the wave being increased gradually until failure of the transformer insulation occurred. With this type of test the breakdown naturally would occur on the tail of the wave. Results of these tests showed insulation breakdown potentials of from 100 to 160 kv. In all cases the breakdown occurred in the insulation between primary and secondary windings and did not involve the core or case.

Bushing Flashover Tests

After the tests on the transformers with and without arrester protection had been completed, the leads were disconnected from the windings and the following bushing flashover tests were performed: (1) wet and dry flashover outside; (2) dry flashover inside. Each test was made with: (1) a 60-cycle voltage; (2) a surge having a front of 50 kv per microsecond; and (3) a surge having a front of 150 kv per microsecond. Some of the transformers had their primary leads taped with several layers of varnished cambric. With this lead insulation the primary bushings withstood surges of 100-kv peak value. Since this potential seemed to be of the order that the winding insulation might be expected to withstand, the tests

Table I—Surge Tests on Transformers With Arrester Protection

External arresters used: 3–5 kv on primary phase leads and 300-volt neutral arrester in primary neutral

		Transformer Voltage, Kv						
Transformer No.	Arresters	Prim. H_1 to Sec. Neut.	Prim. H_1 to Case	Prim. H_2 to Sec. Neut.	Prim. H_2 to Case	Case to Sec. Neut.	Case to Sec. X_1	Case to Sec. X_2
1	External	16.9	15.4	4.1 4.7*	2.9	4.0	2.8	2.2
2	External	18.3	16.9**	7.9 22.2*	6.9	3.4	1.9	1.7
3	External	20.0	19.5**	8.1 23.2*	6.5	2.1	2.0	2.0
4	External	18.0	16.0	4.6 5.2*	3.1	3.3	3.7	3.5
5	External	19.0	16.4	8.9 9.1*	7.1	2.4	3.6	2.6
6	Internal	†53.8 ††53.2	35.6	15.3	9.5	22.8 31.4	22.1	16.4
7	Internal	15.9	13.0	6.7	5.25	2.7	2.6	2.1
8	None	20.0 ‡87.6						
9	None	19.4 §84.0						

* These readings taken with primary neutral arrester disconnected.

** Heavy discharge on measuring gap indicating breakdown from case to secondary after measuring gap sparked over.

† Using both case-to-ground and case-to-neutral gaps.

†† Using case-to-neutral gap only.

‡ Path of flashover: inside case, phase lead to case $1^3/_{16}$ in., case to secondary lead $1^1/_8$ in.

§ Path of flashover: primary phase lead to case, outside over bushing, 1 in., core bolt to secondary jumper, inside $^1/_2$ in.

were not carried to the point of puncturing the lead insulation or flashing the primary bushings. Instead, a piece of No. 22 B&S gage copper wire was coiled around the lead insulation as close as possible to the bushing and connected to the lead. This approximated the condition of completely deteriorated insulation on the leads. Data given in Table II apply to this condition.

On transformers Nos. 1 and 4 the outside of the bushings was taped and painted in accordance with the standard specifications of the Commonwealth Edison Company (Chicago). For transformer No. 1 the bare metal was exposed inside the tank; for transformer No. 4, extra leads were used in place of those furnished with the transformer, in order to avoid cutting the existing leads. All flashover tests were conducted in accordance with A.I.E.E. standard specifications for this type of testing. In general, the data of Table II reveal that transformers Nos. 1 and 4 have somewhat higher bushing flashover voltages, especially inside the tank, than do Nos. 5 and 6. Transformer No. 4 shows higher flashover voltages inside the tank than does transformer No. 1. Of course, in making comparisons from the figures of the table it must be remembered that the flashover voltages for transformers Nos. 5 and 6 apply to the

Table II—60-Cycle and Surge Flashover (Kv) of Transformer Bushings

Barometer . . . . 747–756 mm of mercury
Temperature . . . . 24–26 deg C
Humidity . . . . 40–70 per cent
Precipitation (for wet flashover tests) 0.192–0.205 in. per min
Water resistivity (for wet flashover tests) 6,550 ohms per cu in.

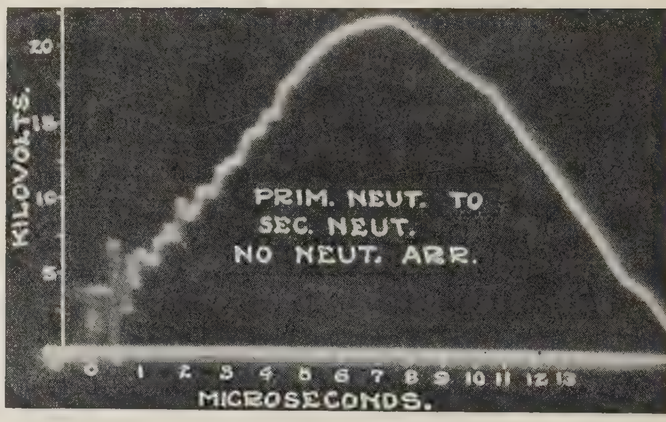
Transformer No.	Voltage Applied	Primary Phase or Neutral Bushing			Secondary Bushing		
		Outside		Inside	Outside		Inside
		Dry	Wet	Dry	Dry	Wet	Dry
1	60 cycle (eff)	49.0	33.0	32.6	48.3	31.3	32.6
	50 kv per µsec	106.0	133.0	61.0	101.0	101.0	66.5
	150 kv per µsec	109.0	107.0	82.0	109.0	102.0	84.5
4	60 cycle (eff)	53.6	27.0	40.6	53.3	29.8	41.3
	50 kv per µsec	96.0	109.0	109.0	99.0	100.0	100.0
	150 kv per µsec	107.0	100.0	109.0	111.0	101.0	109.0
5	60 cycle (eff)	33.3	17.7	26.9	24.2	14.6	16.9
	50 kv per µsec	96.0	78.0	54.5	50.0	50.0	31.5
	150 kv per µsec	100.0	85.3	67.3	52.0	52.0	38.2
6	60 cycle (eff)	36.9	26.8	22.3	35.0	20.2	14.2
	50 kv per µsec	96.0	91.2	52.5	76.5	74.0	33.0
	150 kv per µsec	102.0	102.0	57.5	83.5	80.5	37.0

condition of completely deteriorated lead insulation. Considerable variation is noted in the flashover voltage outside the tank, of transformers Nos. 1 and 4. It seems evident that these are caused by variations in the taping and painting of the bushings. Reasonable care was used in this operation, but evidently uniform results were not obtained. It was interesting to note during the tests that in practically all cases the 60-cycle flashover punctured the tape, while the surge flashover went underneath the tape.

For the 60-cycle bushing flashover inside the tank of transformer No. 4, the values in the table are the values of the first flashover. A large amount of carbonization occurred and unless the leads were removed and the bushings cleaned, the 60-cycle flashover voltage was observed to drop to 65 or 75 per cent of its initial value. This trouble was not noticeable to any extent on the surge flashover tests. It was observed that the inside bushing flashover of transformer No. 4 did not puncture the lead insulation but followed the surface of the porcelain into the metal of the lead.

Data of Table II also indicate that the surge flashover under rain conditions is not materially different from that under dry conditions. In this respect it may be noted here that one of the trans-

With 300-volt neutral arrester



Without neutral arrester

Fig. 9. Potential between primary neutral H_2 and secondary neutral X_1X_3 on transformers (Nos. 2 and 3) with insulation previously broken down

formers, in contrast to the others, was designed so that very little of the drip from the tank fell upon the bushings.

As mentioned previously, the coil insulation of some of the transformers did not receive a severe test. It seemed desirable, therefore, to determine the effects of a more severe surge upon the windings of the transformers. Accordingly, the insulation between the primary and the case on some of the transformers was tested up to the point of primary bushing flashover inside the case as listed in Table II. No evidence of insulation damage was noted in these tests.

Some tests were made also to determine the recovery value, if any, of punctured insulation as the result of the oil filling up the puncture. The 2 transformers which in previous tests had indicated breakdown between the secondary windings and the case were subjected to surges up to the point of

breakdown between the secondary and the case. The following values were obtained in this test:

Transformer	Breakdown, Secondary to Case	Oil Test
No. 2	56 kv	24.8 kv
No. 3	17 kv	25.5 kv

These values would seem to indicate that a transformer in service might have its insulation punctured by a surge and still have sufficient insulation for normal line potential. If the transformer fuse is blown, there is necessarily some time interval before it is replaced. This allows time for the oil to fill the puncture so that when the fuse is replaced the transformer continues to operate as before. Such has been the experience of many companies.

Low Voltage Network Cable of a New Type

A secondary network cable that will burn clear without producing any smoke, inflammable, explosive, or toxic gases during faults has been developed. Tight and loose faults were cleared satisfactorily in a series of tests in underground ducts and vertical conduits without involving adjacent unfaulted phases. Dielectric strength is high and is recovered after exposure to water. The new insulation cannot carbonize and will withstand high temperatures.

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As a RESULT of operating experience on low voltage secondary networks an insistent demand has been built up for a self-clearing secondary cable—one that would burn clear within a comparatively short time even under the most severe fault condition, and furthermore one that would not liberate inflammable, explosive, or toxic gases during the clearing.

In 1929 work was started by the Rockbestos Products Corporation on the development of such a cable and continued until March 1933 when a final series of tests was made. As each stage of development was reached in the laboratory the findings were checked under actual service conditions through the coöperation of the Western Massachusetts Companies who made available a complete testing ground and equipment at their No. 5 substation in East Springfield, Mass. The primary purpose of the March 1933 tests was to demonstrate the performance of this cable under the most adverse conditions experienced in network operation.

Following are the conclusions which were drawn as the result of these tests:

1. These tests clearly demonstrate that under most severe fault conditions the cable insulation gives off no inflammable, explosive, or toxic gases.

2. This cable insulation does not burn and therefore practically no smoke is generated by the insulation as a result of any type of fault.

3. It is possible to enter the manholes for repairs almost immediately after the fault clears.

4. The heat resisting quality of the insulation is clearly demonstrated by the high mechanical strength of the insulation after burn-off. Even adjacent to the burn-off where the copper conductor was fused and where the temperature was estimated to be at least 3,000 deg C, the insulation possessed sufficient mechanical strength to remain practically intact after removal from the ducts. (See Fig. 1.)

5. So far as maximum operating temperatures are concerned the cable insulation does not impose any limitation, since it is unharmed by temperature below the melting point of copper.

6. The insulation of the cable shows practically the same dielectric strength after burn-off as before. Tests were made on sections of cable near the burn-offs after removal from the ducts.

7. While this form of insulation will absorb some moisture if exposed to water, the resulting leakage currents dry out the insulation so that it regains its initial electrical characteristics.

8. The large number of reëstablishments of current flow, following clearing in 2 of these tests (tests 5 and 6, described later) were caused by the accumulation of molten lead and copper in the lower half of the conduit rather than by any characteristic of the cable insulation. This is proved by the comparatively few restrikes in test 17.

9. No difficulty was experienced in removing the insulation from the cables in preparation for the tests.

10. No explosion or fire and practically no smoke was observed when the cables were tested in iron, tile, or soapstone ducts.

11. In spite of the presence of vapors and molten metal, all faults cleared satisfactorily without communication to any part of the system beyond the faulted cables.

12. Single-phase and 2-phase faults cleared without involving the unfaulted phases. Examination of cables after removal showed only short sections of lead sheath melted off the unfaulted cable at the points where faulted cables burned clear, or where there was contact with the hot neutral.

13. Practically no difficulty was experienced in removing the cables from the ducts following the tests.

Test Cables

The cables used in these tests were made up of 4/0 plain copper conductors (19 strands of 0.1055 in.

Written especially for ELECTRICAL ENGINEERING. *Not published in pamphlet form.*

diam each) insulated with a special form of "Rockbestos" insulation having a wall thickness of 0.100 in. and enclosed in a $^5/_{64}$-in. lead sheath. This cable was used in all tests except test No. 17, where non-leaded cables were used. The insulating wall in these cables consisted of felted asbestos impregnated with a special compound. Neutrals in the test sections were of 4/0 bare copper conductors (19 strands of 0.1055 in. diam each).

The "tight" faults were made by removing approximately 12 in. of insulation in the center of the phase conductors to be faulted and tightly binding them and the bare neutral together with copper tie wire, except in test 11, where the neutral was in a separate duct. The "loose" faults were made the same way except that they were bound loosely with a smaller size tie wire.

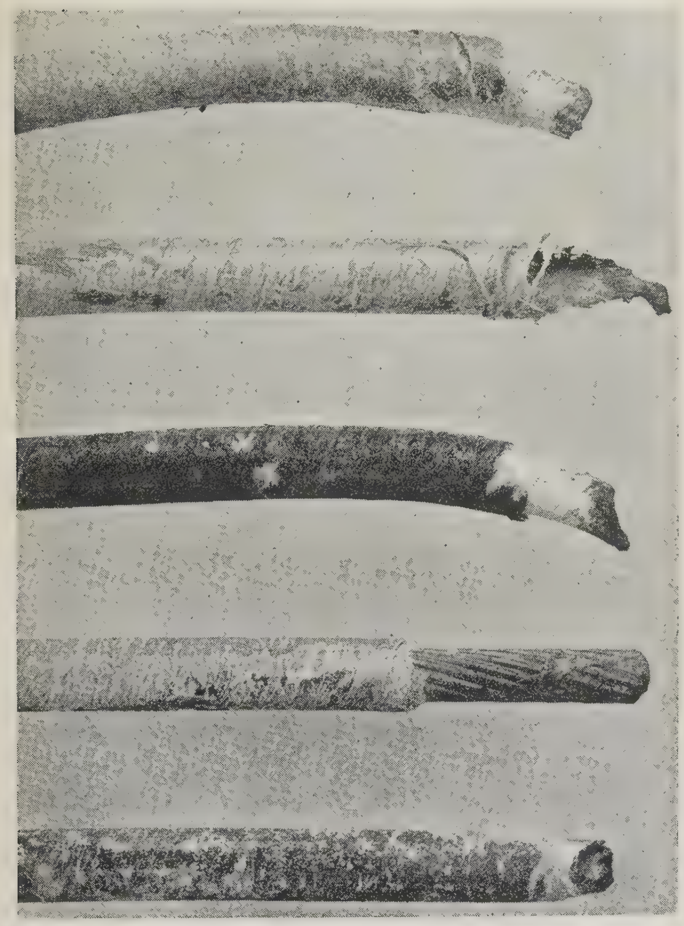

Fig. 1. A group of specially insulated low voltage network cables after being subjected to faults. The discoloration which may be noted is due to copper and lead vapors and grease from dust and from handling. The temperature to which these cables were subjected is estimated to have been 3,000 deg C

In tests 1, 2, 3, 4, and 15 the connections between the test cables and the feeders were wiped lead joints. In all other tests the connections were made with bolted *T* connectors and wrapped with asbestos listing. This method of connection was used to avoid the delay of making wiped lead joints.

Electrical Properties

The dielectric strength of the cables used in these tests is as follows:

1. The dielectric strength of 100 mils of insulation averages 3,725 volts.
2. After prolonged heating for 63 hr at 150 deg C, and while still at that temperature, dielectric breakdown on the 100-mil cable thickness occurred at 2,800 volts, average.
3. After heating 63 hr at 275 deg C and while still at that temperature, breakdown occurred at 2,300 volts, average.
4. After heating 63 hr at 150 deg C and then being cooled to room temperature, breakdown occurred at 3,800 volts, average.
5. After heating 63 hr at 275 deg C and then being cooled to room temperature, breakdown occurred at 3,750 volts, average.

These cables are subjected to the usual routine full reel factory dielectric test of 1,500 volts for 5 min.

Sections of the test cables which had been removed from the ducts were tested. The tested sections were approximately 8 in. from the burn-off. The dielectric breakdown at room temperature on these samples averaged 3,730 volts.

Testing Equipment

A view of the testing equipment is shown in Fig. 2. The duct and manhole arrangement used in these tests is shown in Fig. 3, and the layout of the electrical equipment used is shown in Fig. 4. As indicated, 2 standard construction manholes with 8 duct lines were built outside the substation yard at Substation No. 5, East Springfield, Mass., of the Western Massachusetts Companies. The ducts between the manholes were 2 each of fiber, tile, soapstone, and iron. The tile ducts were 3.25 in. and the others 3.5 in. Each pair of ducts was constructed in a separate concrete envelope so that the pair could be dug up without disturbing the others. The lateral ducts were 3.25-in. tile leading from the manholes into the yard.

Three single-phase 500-kva 25-cycle, 5.7-per cent reactance, 13,800/120-volt oil-insulated self-cooled transformers and 3 specially built reactors were located in a spare 13-kv oil circuit breaker bay. The transformers were operated at 60 cycles con-

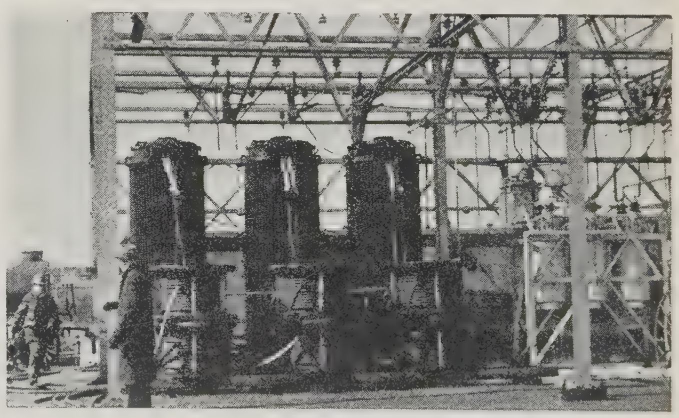

Fig. 2. Transformer and reactor testing equipment used for conducting tests on the new cables at No. 5 substation, East Springfield, Mass., of the Western Massachusetts Companies

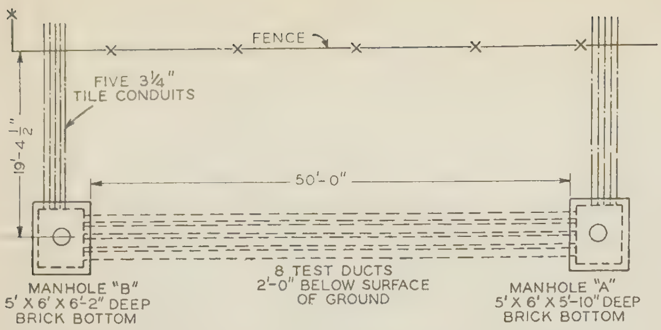

Fig. 3. Plan showing duct and manhole arrangement for conducting tests on cables at No. 5 substation

nected delta on the primary and 4-wire 120/208-volt star on the secondary. The open circuit secondary voltages to ground measured 120, 120, and 121 volt. All switching was done at 13.8-kv on the primary side of the transformers. The total safe short-circuit capacity of the testing equipment was 6,000 amp.

The reactors were single phase and each consisted of 2 48-in. cable reels wound with 12 turns of 1,000,000 cir-mil cable and provided with variable taps. The iron hubs and through-bolts were removed from the reels and brass bolts and wood braces substituted. The 2 reactors of each phase were mounted on top of each other and were arranged for either series or parallel connection with different tap combinations.

For reading current in each phase and ground, 4 5,000-volt 25/60-cycle 6,000/5-amp through-bar type indoor current transformers and 4 5-amp high speed graphic ammeters were used. The chart speed was 1.5 in. per sec. Direct reading ammeters were used to check the graphic ammeters.

The jumpers from the transformers to the reactors and the leads from the reactors to the feeders were made from 2,000,000-cir-mil cable. The phase feeders from the reactor leads inside the substation yard through the lateral ducts into the manholes outside the yard were parallel 4/0 cables insulated exactly like the test cables. The neutrals from the reactor leads through the lateral ducts to the test cables were 500,000-cir-mil bare copper. Faults could be fed from one end only or from both ends simultaneously.

For the vertical riser tests a pole was erected outside the substation yard. Two 3.5-in. iron conduits were supported on this pole by means of channel iron cross pieces. The iron conduit and channel iron sections were all grounded. Four 2,000,000-cir-mil test leads were carried to the top of the pole to feed the fault from that point. An additional set of 2,000,000-cir-mil leads were used to feed the fault from the bottom of the pole. Transite board was used to protect the feeders and joints from molten lead.

Observations and Test Results

Seventeen tests were conducted; these were designed to include all types of fault conditions encountered in network operation. Progress of the tests was recorded on the graphic meters and checked from the direct reading meters. All tests were checked with 3 stop watches. Observers were stationed at each manhole for the underground tests and noted any special phenomena occurring. Photographs were taken on a regular schedule throughout the entire test program.

Data and observations taken during the tests are summarized in the following paragraphs. In each of these paragraphs, information is given on: (1) test number; (2) type of fault; (3) whether power is supplied from one or both ends of the cables; (4) maximum current at the fault, averaged for all phases, and current in neutral; (5) approximate clearing time averaged for both ends of all 3 cables; (6) data on the momentary reëstablishments of the current after the first clearing; (7) duration of tests, that is, total time

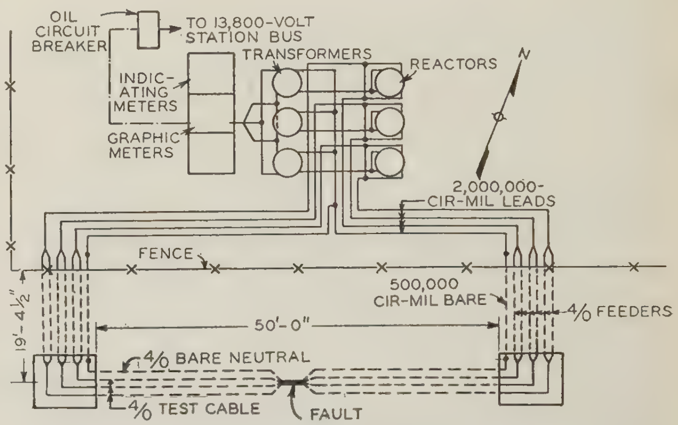

Fig. 4. Plan showing electrical layout for conducting tests on cables at No. 5 substation

during which voltage was applied to the cable; and (8) various remarks of the observers recorded during the tests.

Test 1. Three-phase tight fault in center of tile duct. Power supplied at both ends. Maximum current at fault averaged 6,000 amp in 3 phases and was 4,920 amp in neutral. Average clearing time, 3 min. One to 3 momentary reëstablishment of current flow occurred in each phase, between 3 and 3.5 min from the start of tests; reëstablishment current average 2,250 amp. Test duration, 10 min.

In 2 min from the start of test a light vapor was noted at east manhole cover. One minute later this same trace of vapor appeared at west manhole cover and simultaneously at the mouths of the west lateral ducts. This disappeared with the clearing. At 4 min copper vapor was noted at the east manhole cover. Manholes were clear and men were working in manholes 6 min after shutting off current. All 3 phases burned off 10 ft from duct mouth in east manhole. In west manhole one phase cleared in duct and other 2 phases burned off in manhole. Lead sheath melted off all conductors.

Test 2. Three-phase tight fault in center of iron duct. Power supplied at both ends. Maximum current averaged over 6,000 amp in phases, with 4,550 amp in neutral. Clearing time, 3 min. Two reëstablishments occurred on phase A, one each on phases B and C: all occurred between 3 and 3.5 min from starting time; current averaged 2,300 amp. Duration of test, 9 min.

A light steam-like vapor was noted at east manhole cover as phases cleared. At 3 min similar vapor noted at west manhole cover at reëstablishment of A phase. All 3 phases cleared in west manhole. On east end one phase burned off in manhole and 2 phases burned off at duct mouth. Manhole covers off one minute after test and a man went down immediately to recover blower

hose which accidentally dropped in. No ill effects. Lead sheath melted off all conductors.

Test 3. Three-phase tight fault in center of soapstone duct. Power supplied at both ends. Maximum current averaged over 6,000 amp in phases, and was 4,520 amp in neutral. Clearing time averaged 2.5 min. Over 20 reëstablishments occurred on each phase, but had stopped at 3 min, 37 sec, after start of test. Duration of test, 10 min.

Slight puff of metal vapor in both manholes on clearing. Several puffs from restrikes noted at west manhole. All cables burned off in duct on both ends. Cables intact in manholes. Men down to work 4 min after current off. Some of the lead sheath remained on cables. Insulation was in very good condition where lead had been melted. One phase cleared in Y-joint in manhole. Later investigation showed this due to error in connecting parallel feeders to phase leads.

Test 4. Three-phase loose fault 10 ft from center of tile duct. Power supplied at both ends. Maximum current averaged over 6,000 amp in phases and was 3,240 amp in neutral. Clearing time, 52 sec. All phases were then reëstablishing up to between 4 and 5 min from start of test, the current varying up to approximately 5,000 amp in phases. Duration of test, 10 min.

Puffs of copper vapor noted at both manholes as phases reëstablished. Shortly afterward white smoke issued from both east and west lateral ducts in the yard. Parallel feeders in the yard jumped continuously until final clearing. Manhole covers off immediately after test. However, men were not able to enter manholes immediately due to the large amount of copper and lead vapor present. Cables in west manhole intact including lead sheath. Burn-off occurred in the duct. At east end arc carried back and lead melted off conductors in east manhole. Lead sheath practically intact on west end of test length except for a section about 3 ft back from point of burn-off.

Fig. 5. Arrangement for conducting vertical riser tests, showing test No. 5 in progress

Test 5. Three-phase loose fault in center of vertical iron duct. Power supplied at both ends. Maximum current averaged 5,100 amp in phases, and was 5,520 amp in neutral. Clearing time, 5 sec. Between 20 and 30 reëstablishments occurred in each phase with current varying between zero and 4,890 amp; final clearing on all phases occurring in 44 sec. Duration of test, 5 min, 40 sec.

During the first minute a slight amount of smoke appeared at top of riser followed by heavy arcing and resultant vapor. Arc burned through iron riser, setting fire to the weatherproof leads which were feeding the top of the fault and which were adjacent to the point where the arc burned through the pipe. (See Fig. 5.) All phases cleared inside the duct. Bottom ends of faulted cables pulled out of duct by hand very easily. Lead sheath intact on upper half with exception of area not over one foot above point of burn-off. Lower half had some lead sheath remaining. Insulation hardly discolored.

Test 6. Two-phase tight fault in center of vertical iron duct. Power supplied at both ends. Maximum current was over 6,000 amp in each of the 2 phases (A and B) and neutral. Clearing time varied between 1 min, 25 sec, and 3 min, 32 sec. Reëstablishments involving the third phase occurred up to 3.5 min. Duration of test, 8.5 min.

Slight smoke noticed at top of pipe and at bottom leads at approximately 2 min. Molten lead began to drip shortly after. Heavy arc cut through bottom of riser about one foot long. Phase wires and neutral were bound together with asbestos listing at bottom of riser. This caused an accumulation of lead at this point. The lead sheath entirely gone except on phase C, which was only slightly melted at point of burn-off. Phase A burned off both sides of fault. Phase C was unfaulted but came in at 2 min due to restrike at bottom of pipe where arc was maintained because of accumulation of lead where listing was tied around the cables.

Test 7. Single-phase tight fault in center of vertical iron duct. Power supplied at both ends. Maximum current over 6,000 amp in the one phase and neutral. Clearing time, 2 min, 6 sec, at one end and 2 min, 22 sec, at other end of faulted cable. No reëstablishment occured on any phase. Duration of test, 5.5 min.

Slight smoke at both ends of riser after approximately one minute. Neutral became red hot in 2 min and dropped down. Neutral burned off at both ends of riser, causing slight scar on lead sheath of A and B phase cables at these points. A and B phase cables, which were not faulted, were not involved.

Test 8. Three-phase tight fault in center of vertical iron duct. Power supplied at both ends. Maximum current averaged 4,600 amp in phases and was 5,280 amp in neutral. Clearing time averaged about 4 min. Reëstablishment occurred up to about 6 min. Duration of test, 10 min.

Light smoke issuing from bottom in 2 min; lead dripped in 3 min followed by heavy arcing at the bottom, but with very little smoke. Arcing burned through riser about half way up. Phases cleared at the top of the riser. Lead sheath gone except for distance of about 3 ft at top of cable.

Test 9. Three-phase tight fault with cables on top of ground. Power supplied at one end only. Maximum current, about 4,100 amp in phases, and 3,240 amp in neutral. Clearing time on each phase from 1.5 to 2 min. No reëstablishments on any phase. Duration of test, 5 min.

Slight white steam-like vapor at fault in about 30 sec, and at one minute at terminals. Lead melted off in about one minute. All phases cleared cleanly at the transite barrier which was used to protect the feeders. Insulation in very good condition.

Test 10. Three-phase tight fault in center of iron duct. Power supplied at both ends. Maximum current averaged 3,900 amp in phases and was 4,100 amp in neutral. Clearing time, about 9 min. Four momentary reëstablishments occurred on one phase and 2 on another, at between 9 and 10 min from start of test. Duration of test, 15 min.

No smoke or vapor whatever noted. Two phases burned off inside duct mouth in west manhole and one in the manhole, and 2 phases, A and B, burned off at duct mouth in east manhole; phase C cleared in duct. Lead practically all melted off conductors, and insulation in good condition.

Test 11. Two-phase tight fault in center of tile duct; neutral in separate duct. Power supplied at both ends. Maximum current

Fig. 6. Clearing of cables at top of vertical iron riser in test No. 17. All phases burned off clean

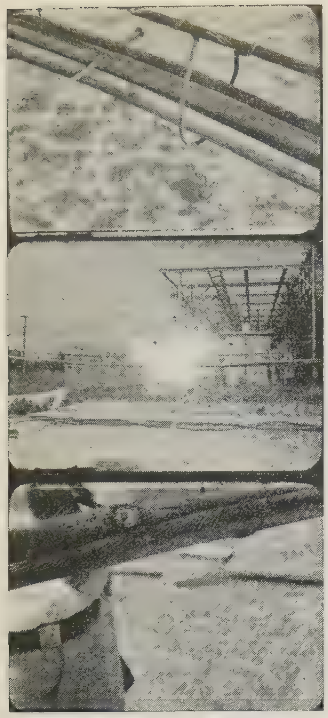

Fig. 7 (above). Tests of the new cable in an overhead network, showing, first, the single phase "spike fault," second, what happened immediately the switch was closed, and third, the result. Half the spike was melted off together with the adjacent lead sheath, without injuring the insulation. The line continued to operate normally after the arc was extinguished. The bare neutral was slightly melted where it lay on the spike. Total clearing time about 0.5 sec

about 4,100 amp in 2 phases and 1,620 amp in neutral. Clearing time, about 8.5 min. Reëstablishments occurred on the 2 phases up to about 9.5 min. Duration of test, 14 min.

Slight puffs of vapor noted at reëstablishments. One phase cleared in duct and one phase cleared in manhole. Third phase intact including lead sheath.

Test 12. Three-phase tight fault in center of fiber duct on top of ground. Power supplied at both ends. Maximum current averaged 5,700 amp in phases and was 4,860 amp in neutral. Clearing time on different phases, 2 min, 40 sec to 5 min, 28 sec. Reestablishments occurred on all 3 phases up to 5 min, 28 sec. Duration of test, 8 min.

Light smoke started in about 2 min, getting heavier, then lighter, and then heavier again. This turned to dense yellow and finally black indicating burning of the fiber. Heavy fire and arcing over each half of length of duct occurred at about 4 min. Center of duct broke open about 30 sec later. Cables burned off cleanly at east end of duct. Due to the continuous arcing entire east half of duct and test cables were destroyed.

Test 13. Three-phase tight fault in center of fiber duct. Power supplied at both ends. Maximum current averaged some 6,000 amp in phases and was 4,800 amp in neutral. Clearing time, about 3.5 min. One momentary reëstablishment occurred on one phase after 4 min; current was 1,780 amp. Duration of test, 10 min.

Light smoke in 2 min noted at west manhole. This turned black almost immediately and then to yellow in less than 2 min. No movement of west manhole cover. Light smoke in 3 min from east manhole and puff at 4 min. Explosion at 5 min which raised cover about 6 in. on one side. Another slight explosion at 7 min, raised cover about 2 in. Puffs continued for another minute. When covers were raised dense yellow smoke issued from both manholes. Blowers were started immediately and men entered manholes 12 min after current off. Phases in west end all cleared in manhole. In east manhole one phase cleared at duct mouth and one phase cleared in the manhole 3 ft from duct mouth on the rack and third phase cleared in the duct. About 10 ft from the east manhole the cables were stuck in the duct due to a conglomerate mass of lead and fiber, so that they could not be pulled out for examination.

Test 14. Three-phase loose fault in center of fiber duct. Power supplied at both ends. Maximum current averaged 4,600 amp in phases, and was 2,590 amp in neutral. Clearing time, 3 min. Reëstablishments continued up to 4 min, 9 sec, the strikes occurring at the rate of 100 per min for part of this period, as a result of this being a loose fault. Duration of test, 8.5 min.

An explosion raised both manhole covers slightly almost immediately with the closing of the switch. Heavy yellow and black smoke issued around both manhole covers and from both sets of lateral ducts. It was possible to clear manholes with blowers so covers were replaced and covered with sand during noon hour. Ducts were still burning when manhole covers were removed and duct lines and manholes were filled with water to extinguish fire. All phases cleared inside of duct mouth.

Test 15. Three-phase tight fault in center of iron duct; joints leaded, and manholes full of water, so that ducts were flooded.

Fig. 8 (left). Taking a shot at the new type of cable in an overhead network set-up. The middle photograph shows the fault when the buckshot and deer slug hit the cables, and the third photograph shows the result. The faults cleared immediately without any reëstablishment

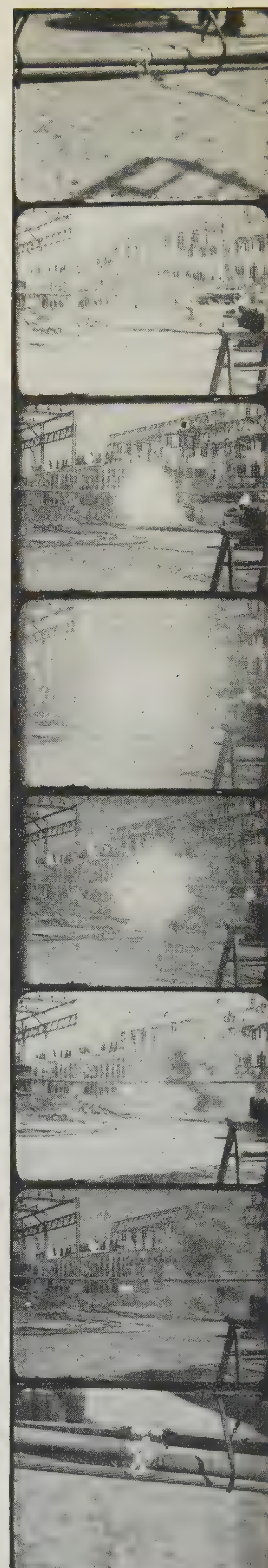

Fig. 9 (right). Performance of a 3-phase tight fault on an overhead network set-up. The first of these 8 views shows the method of making the fault with several turns of copper tie wire around the cables of all 3 phases and the bare neutral, while the last view shows the clean clearing. The 6 intermediate views show the complete progress of the clearing. The action started immediately with the closing of the switch. These pictures taken at the rate of 8 per sec showed that clearing occurred in less than 1 sec

Power supplied at both ends. Current averaged approximately 6,000 amp in phases and was 5,220 amp in neutral. Phases B and C cleared in 8.5 to 10 min, but the dissipation of heat generated in phase A cable was so rapid that it could not clear. No reëstablishments on phases B and C. Test discontinued after 14 min to avoid overloading transformers.

Slight steam-like vapor issued from lateral ducts at 4 min and continued throughout test. No smoke or vapor from either manhole. After removing the cables from the duct it was found that in phases B and C the conductor had burned clear, leaving a gap approximately 2.5 in. long inside the insulating tube, leaving the insulation and lead sheath intact. Apparently the copper which originally filled the gap had fused or vaporized and flowed into the space created by the melting of the stranded conductor on either side of this point. One theory of this peculiar effect is that this was a high point in the cable, perhaps where it crossed over one of the other legs, and when the conductor finally reached a molten state the copper flowed back to lower levels on both sides of the break. The fact that the lead sheath was still intact may be accounted for, first, by the presence of the surrounding water which prevented its melting and second, because whatever gas was given off by the insulation, even under the heat of the molten copper was of such small amount that no appreciable internal pressure was produced.

Test 16. This test was designed to show the recuperative powers of the insulation when exposed to water. No graphic records were taken. The test conductors consisted of 3 20 ft lengths of leaded conductor for the phases and a 20 ft neutral. In the center of the phase conductors the lead was removed for about 2 ft; the lead was belled open to permit free entrance of the water. The phase conductors and the neutral were then bound together with copper tie wire. Current was supplied from one end only, and was turned on with cables dry in the air to make sure no accidental fault had occurred in assembling. Next the cables were immersed with ends exposed, in a 25-gal tank of water for 5 min. At this time they were removed and set up on blocks in the open air and current fed from one end. Initial current was approximately 120 amp, which dropped to a value too small to read on the meters in less than 3 sec. Readings had to be approximate due to the limitation of the indicating meters. Steam came from the insulation for approximately 10 min and had nearly ceased when the current was cut off at 10 min. The cables were then replaced in the tank of water and allowed to soak for 5 min. Current was again applied with cables in water for 12 min. Initial current 720 amp, but this dropped in less than 3 sec to a value too small to read on the meters. At 6 min steam came out of the strands at the ends of the conductors and continued throughout test. The vapor began to rise from the water at about 8 min and continued until test was shut off. After the test the temperature of the water was luke warm. The hands could be placed in the water with no discomfort. Examination of the insulation showed no apparent change. Subsequently, other tests on cables submerged under water, and having the lead sheath drilled with pin holes, were conducted. Three of these tests extended for 28 days and no failure of the insulation had been recorded. Another test was conducted which demonstrated that if a dead cable with a defective sheath, which had lain submerged in water for a long period were suddenly energized, the internal pressure produced would be insufficient to rupture the sheath.

Test 17. Three-phase tight fault in center of vertical iron duct; unleaded cables. Power supplied at both ends. Maximum current averaged 5,750 amp in phases and was 4,400 amp in neutral. Clearing time, approximately 3 min. An average of 4 reëstablishments occurred on each phase between 3 and 4 min from the start of the test, with currents between 2,000 and 5,000 amp. Duration of test, 8 min.

Light smoke at top of riser after 2 min. Copper ran out of bottom of duct in 3 min. Heavy arcs top and bottom continued for 30 sec burning cables clear at top and bottom of riser. (See Fig. 6.)

Later Tests

Other tests, made after the March 1933 tests described above, were taken on lead covered cables suspended in air to give the equivalent of an overhead network. These later tests and the results are shown graphically in Figs. 7, 8, and 9.

The Induction Motor on Unsteady Loads

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THE approximate calculation of cyclic irregularity and variation in motor current due to a steady load with a sinusoidally varying load superposed is dealt with in this letter. For the case of a slip ring motor at a given torque, the effect of varying the slip by means of rotor resistance or separately driven cascaded commutator machine is briefly discussed and a numerical sample is given. A list of the symbols used follows:

T_{max} = maximum load torque in lb-ft on shaft

T_{min} = minimum load torque in lb-ft on shaft

T = mean load torque in lb-ft on shaft $= \dfrac{T_{max} + T_{min}}{2}$

$K = \dfrac{T_{max} - T_{min}}{2T}$

ω_{max} = maximum angular velocity of shaft in radians per sec $= 2\pi\, rps_{max} = \omega\left(1 + \dfrac{C}{2}\right)$

ω_{min} = minimum angular velocity of shaft in radians per sec $= 2\pi\, rps_{min} = \omega\left(1 - \dfrac{C}{2}\right)$

ω = mean angular velocity of shaft in radians per sec $= 2\pi\, rps_{mean} = \omega_{syn}\,(1 - S)$

$\omega_{syn} = 2\pi\, rps_{synchronous}$

C = cydic irregularity $= \dfrac{\omega_{max} - \omega_{min}}{\omega}$

S = slip corresponding to shaft torque T

ϕ = angle of lag in radians

WR^2 = weight of rotating masses in lb $\times$ (radius of gyration in ft)^2

g = 32.2

t_p = periodic time of disturbance, i. e., time per complete cycle

f = frequency of disturbance $= \dfrac{1}{t_p}$

i = stator current corresponding to a shaft torque T (rms amp)

$\theta = 2\pi$ ft

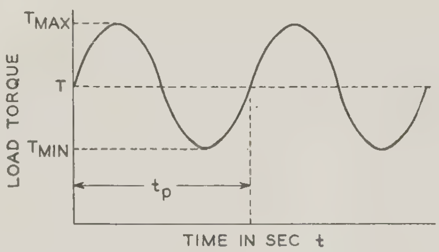

Fig. 1. Typical curve of load torque vs. time

A typical curve is shown in Fig. 1. The derivation of the equations follows:

At any time t:

Load torque $= T[1 + K \sin(2\pi ft - \phi)]$

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Angular velocity of shaft $= \omega\left(1 + \frac{C}{2}\sin 2\pi ft\right)$

Torque given out by rotating masses $=$

$$\frac{WR^2}{g}\frac{d\omega}{dt} = \frac{WR^2}{g}\pi fC\omega\cos 2\pi ft$$

Motor torque $= T\left(1 + \frac{C}{2S}\sin 2\pi ft\right)$, assuming that the slip is proportional to load

Load torque $=$ torque given out by rotating masses $+$ motor torque

$$T[1 + K\sin(2\pi ft - \phi)] = \frac{WR^2}{g}\pi fC\omega\cos 2\pi ft + T\left(1 + \frac{C}{2S}\sin 2\pi ft\right)$$

Dividing by TK and simplifying we obtain

$$\sin(2\pi ft - \phi) = \frac{WR^2}{gTK}\pi fC\omega\cos 2\pi ft + \frac{C}{2SK}\sin 2\pi ft$$

but, by trigonometry

$$\sin(2\pi ft - \phi) = \sin\phi\cos 2\pi ft + \cos\phi\sin 2\pi ft$$

$$\therefore \sin\phi = \frac{WR^2}{gTK}\pi fC\omega \qquad \cos\phi = \frac{C}{2SK}$$

but $\sin^2\phi + \cos^2\phi = 1$

$$\therefore \left(\frac{WR^2}{gTK}\pi fC\omega\right)^2 + \left(\frac{C}{2SK}\right)^2 = 1$$

$$\therefore C^2\left[\frac{(2SWR^2\pi f\omega)^2 + g^2T^2}{4K^2g^2T^2S^2}\right] = 1$$

whence

$$C = \frac{2KgTS}{\sqrt{g^2T^2 + (2SWR^2\pi f\omega)^2}}$$

Dividing both numerator and denominator by gTS

$$C = \frac{2K}{\sqrt{\frac{1}{S^2} + \left(\frac{\omega\, 2\pi fWR^2}{gT}\right)^2}}$$

but

$$\omega = \omega_{syn}(1 - S)$$

$$\therefore C = \frac{2K}{\sqrt{\frac{1}{S^2} + \left(\frac{\omega_{syn}(1 - S)\, 2\pi fWR^2}{gT}\right)^2}} \tag{1}$$

When the angular velocity of the shaft increases, the current decreases. Let us further assume that the load current drawn from the line is proportional to torque, and we obtain

$$\text{Instantaneous current} = i\left(1 - \frac{C}{2S}\sin 2\pi ft\right) \tag{2}$$

$$\text{Maximum current} = i\left(1 + \frac{C}{2S}\right) \tag{3}$$

$$\text{Minimum current} = i\left(1 - \frac{C}{2S}\right) \tag{4}$$

The current variation from the mean value of i is therefore $\pm \frac{iC}{2S}$ but from eq 1

$$\frac{iC}{2S} = \frac{iK}{\sqrt{1 + \left\{\frac{2\pi fWR^2}{gT}\omega_{syn}(1 - S)S\right\}^2}} \tag{5}$$

We are interested in the value of slip at full load and mean torque which gives us the minimum current variation, and by inspection it is obvious that for this condition $(1 - S)S$ must be a maximum. Differentiating this quantity and equating to zero, we obtain

$$\frac{d(1 - S)S}{dS} = 1 - 2S = 0$$

$$\therefore S = \frac{1}{2}$$

That is, for minimum current variation the slip at mean torque is to be 50 per cent.

Such a large value of slip cannot, however, be permitted as the losses in the resistances introduced in the secondary circuit will be excessive. In practise therefore it is always necessary to allow larger current peaks to take place and to fit a suitable flywheel when constant resistance values are inserted in the rotor circuit. It is interesting to note that by regulating the amount of resistance inserted in proportion to torque or even inserting a large value of resistance when full load mean torque is reached as in the Ilgner system, the current peaks can be reduced. The effect of the sinusoidal variation of current is to increase the copper losses of both stator and rotor.

If we designate the normal copper loss for a steady torque T by i^2r, then, since by eq 2 the instantaneous current is given by $i(1 - \frac{C}{2S}\sin 2\pi ft)$, it is obvious that the copper losses of the same motor working with a cyclic speed variation will be $i^2r\left(1 - \frac{C}{2S}\sin\theta\right)^2$ at any instant, where $\theta = 2\pi ft$. Hence the ratio of $\frac{\text{copper loss with cyclic speed variation}}{\text{copper loss with steady torque } T}$ for one cycle will be

$$\frac{1}{2\pi}\int_{\theta=0}^{\theta=2\pi}\left(1 - \frac{C}{2S}\sin\theta\right)^2 d\theta = \left\{1 + \frac{1}{2}\left(\frac{C}{2S}\right)^2\right\} \tag{6}$$

Thus for a current irregularity of $\frac{C}{2S} = 1$, the current from eq 2 has a minimum value of $i\left(1 - \sin\frac{\pi}{2}\right) = 0$, and a maximum value of $i\left(1 + \sin\frac{\pi}{2}\right) = 2i$ and thus varies between 0 and 2 times the steady current value; the ratio of $\frac{\text{copper loss with cyclic speed variation}}{\text{copper loss with steady torque } T} = 1.5$ by substitution in eq 6. In other words, if a motor works with considerable cyclic irregularity and the temperature rise on steady load is just within a safe limit, dangerous temperatures may be reached.

So far we have assumed that the torque given by the motor is proportional to slip; however, if the maximum slip denoted by $S + \frac{C}{2} - \frac{SC}{2}$ reaches anywhere near the stalling point of the motor, the torque is no longer proportional to slip and the motor will stall. In some cases the motor may

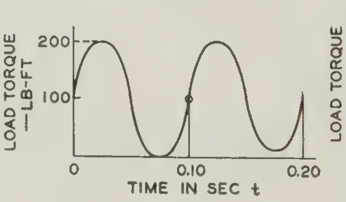

Fig. 2. Example 1

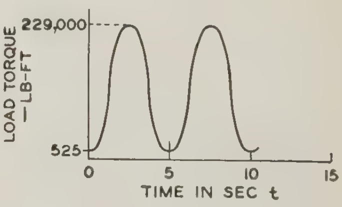

Fig. 3. Example 2

even act first as an induction motor, then as an induction generator when K becomes greater than unity and the inertia of the rotating masses is negligible.

It is interesting to note that so long as the mean torque is positive, there is some theoretical value of flywheel which will stop the motor from surpassing

synchronism. In practise we rarely get a sinusoidally varying torque curve but we can always get an equivalent sine curve to enable us to calculate c.

Example 1

Induction motor, 20 hp, 955 rpm on full load (see Fig. 2.)
WR^2 of motor and coupled masses 65 lb-ft²

$$T_{max} = 200 \; T_{min} = 0 \qquad T = \frac{200 + 0}{2} = 100$$

$$K = \frac{200 - 0}{2 \times 100} = 1.$$

ω_{syn} = 104.5 radians per sec
t_r = 0.10
f = 10
Slip at full load torque of 110 lb-ft = 0.045
Slip at mean torque of 100 lb-ft = 0.0408
From eq 1

$$C = \frac{2 \times 1}{\sqrt{\frac{1}{0.0408^2} + \left\{\frac{104.5 \times 0.9592 \times 2\pi\, 10 \times 65}{32.2 \times 100}\right\}^2}}$$

$$= \frac{2}{\sqrt{602 + 16100}}$$

$$= 0.0155$$

$$\text{Maximum slip} = S + \frac{C}{2} = 0.0408 + 0.0155 = 0.0563$$

$$\text{Current variation} = \pm \frac{iC}{2S} = \pm \frac{0.0155i}{2 \times 0.0408} = \pm 0.19i$$

$$\text{Effective copper loss from eq 6} = 1 + \frac{1}{2}\, 0.19^2 = 1.018$$

Example 2

A 5,000-hp 490-rpm rolling mill motor (see Fig. 3) has to drive a cyclically varying load, the maximum measured horsepower being 20,000 hp at 460 rpm when the material goes through the rolls, the rolling period being 5 sec. The horsepower required to drive the rolls light is 500 hp at 499 rpm. The WR^2 of the motor, flywheel and drive is 1,600,000 lb-ft². The normal full load current at 5,000 hp is 100 amp. Find the rotor resistance to restrict current to 280 amp.

In many instances such as the above, the torque wave form may not be a sine wave, but a sufficiently accurate answer may be obtained by assuming an equivalent sine wave

Calculation A. No external rotor resistance

T_{max} = 229,000 lb-ft — K = 1 (approx.)
T_{min} = 525 lb-ft — Slip at full load torque = 0.02
T = 114,762 lb-ft — Slip at 114,762 lb-ft = 0.0427
ω_{syn} = 52.1 radians per sec
Amperes = 100 — f = 0.20
Amperes = 214

$$\text{From eq 5:}\quad \frac{iC}{2S} = \frac{214 \times C}{2S}$$

$$= \frac{214 \times 1}{\sqrt{1 + \left(\frac{2\pi\, 0.2 \times 1{,}600{,}000 \times 52.1 \times 0.9573 \times 0.0427}{32.2 \times 114{,}762}\right)^2}}$$

$$\therefore \frac{iC}{2S} = 214 \times 0.66 = 141 \text{ amp}$$

Max current = 214 + 141 = 355 amp

Calculation B. External resistance in rotor to give full load slip = 0.06

Slip at full load torque = 0.06 — Amperes = 100
Slip at 114,762 lb-ft = 0.128 — Amperes = 214

$$\frac{iC}{2S} = \frac{214 \times 1}{\sqrt{1 + \left(\frac{2\pi\, 0.2 \times 1{,}600{,}000 \times 52.1 \times 0.872 \times 0.128}{32.2 \times 114{,}762}\right)^2}}$$

$$= 214 \times 0.3 = 64 \text{ amp}$$

Max current = 214 + 64 = 278 amp

Conclusion

The foregoing equations provide useful correlation of the motor slip, WR^2 of flywheel, frequency of disturbance, and peak current drawn from line, and are of importance for prediction of the performance of a proposed drive, especially with regard to the peak current and consequently noise emitted by motor in compressor drives and rolling mills.

A Sequence Relay for Network Protectors

Successful operating experience has been obtained with a phase sequence relay for operating protectors on low voltage a-c distribution networks. Unnecessary operations of protectors are shown to have been practically eliminated by the use of this sequence relay. The design of these relays and operating experience obtained with them are described in this article, which is a companion article to that by H. R. Searing and R. E. Powers in this issue.

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PROTECTORS on many low-voltage distribution networks of today operate needlessly several thousands of times each year due to current reversals caused by regenerative loads and difference in loading at various points in the network. Such reversals can be permitted without tripping the protectors and yet maintain a desirable selective tripping characteristic by use of the phase sequence scheme of relaying described in the companion article "Sequence Principles Used for Network Relaying." This scheme makes use of the fact that practically all power reversals, other than fault conditions, are inherently balanced and that operation of a directional relay can be initiated easily by

Essentially full text of "A Sequence Relay for Network Protectors" (No. 33-17) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

simple switching operations which draw negative phase sequence currents from the network.

The sequence relay which has been designed in accordance with the theory given in the companion paper, and described in this paper, performs the dual function of phasing and tripping. Its operating characteristics, as shown in Fig. 1, in general are

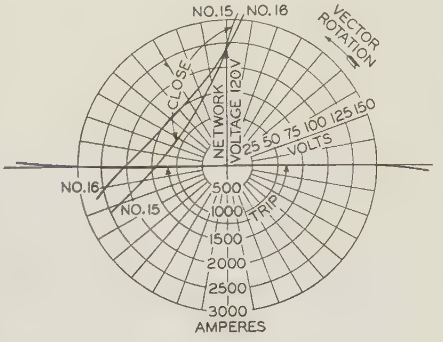


Fig. 1. Operating characteristics of the phase sequence relay for network protectors, assuming balanced 3-phase conditions and 1,600-amp currents transformers having a 1,600/5 ratio

suited to application on low voltage distribution systems.

Construction

Structurally the sequence relay consists of a single induction-disk directional element and 2 overcurrent elements, energized through suitable current and voltage filters. The relay, with the exception of 2 resistors and a phasing lamp, is mounted within a standard network relay case as shown in Fig. 2. The schematic diagram, Fig. 3, indicates the various elements of the relay and the circuits employed. The control circuit, which is not shown, is energized through contacts on the directional element.

Potential Filter

The potential filter consists of an autotransformer and a reactor, mounted in the base of the relay, and an external resistor. Composite diagrams, Figs. 4, 5, and 6, illustrate the operation of this filter under balanced and unbalanced conditions, and show that the relay voltage obtained is proportional to the positive phase sequence voltage of the system and removed from it by a constant angle.

The reactor-resistor combination, connected across E_c in Figs. 4, 5, and 6, has an impedance angle of 60 deg. The autotransformer is tapped at approximately its mid-point. It will be noted that the open circuit relay voltage obtained, E_R, is equal to the vector sum of the voltage rise through the resistor and the induced voltage in the autotransformer. It is proportional to the positive phase sequence voltage E_{a1} of the distribution network and leads it by 120 deg.

The magnitude of the open circuit relay voltage E_R is determined by the ratio N of the external resistance to the sum of the external resistance plus the a-c resistance of the reactor.

$$N = \frac{R}{R+r} \qquad E_R = N\sqrt{3}\,\frac{E_{A1}}{2}$$

where

R = external resistance
r = a-c resistance of the reactor

The current in the potential circuit will lag the open circuit potential coil voltage by an angle that is a function of the series impedance of the potential coil and voltage filter.

Z_F = equivalent impedance of voltage filter

$$Z_F = \frac{R}{4}(4 - N + j\sqrt{3}N)$$

Fig. 2. Sequence relay for network protectors, consisting of 3 elements and suitable current and voltage filters, mounted within a standard network relay case

For accurate measurements of positive phase sequence voltages the resistance of the autotransformer winding must be kept relatively small.

Current Filter

The current filter illustrated in Fig. 7 consists of the current coil of the directional element and a contactor type positive phase sequence current relay connected in series Z_1, a reactor Z_2 and a negative phase sequence current relay of contactor type Z_3, all mounted within the main relay case. An external resistor Z_4 completes the bridge type filter. Four current transformers, cross connected, in Fig. 3, to eliminate zero phase sequence currents from the relay, are used to energize the current filter. Vector diagrams in Figs. 8, 9, and 10 indicate its operation under various conditions.

The currents $I_{C'}$ and $I_{A'}$ from the cross-connected current transformers pass through the current filter

as indicated in Fig. 7. Current $I_{C'}$ divides into equal parts (I_W and I_X) separated by a phase angle of 60 deg as shown in Figs. 8, 9, and 10. Current $I_{A'}$ divides in a similar manner into I_Y and I_Z.

The positive phase sequence vector diagram illustrated in Fig. 8 shows the currents through Z_1 (I_X and I_Y) adding to give a positive phase sequence relay current I_R equal to the $\sqrt{3}$ times the positive phase sequence current of the distribution network, and leading it by 150 deg. The currents through the negative phase sequence relay Z_3, (I_W and I_Z) are equal and opposite and therefore cancel.

In the negative phase sequence diagram, Fig. 9, which illustrates conditions obtained when phases B and C are interchanged, the current vectors I_X and I_Y which pass through the positive phase sequence relay cancel. Current vectors I_W and I_Z which pass through the negative phase sequence relay add up to equal the $\sqrt{3}$ times the negative phase sequence current of the system.

Inspection of the unbalanced current vectors in Fig. 10 again shows the positive phase sequence relay current to be the $\sqrt{3}$ times the positive phase sequence current in the system and leading it by 150 deg. The negative phase sequence current present in the system condition illustrated also is shown. As only positive phase sequence current is used in the directional element of the relay, we are not interested in the phase position of the negative phase sequence current.

Addition of current and voltage vectors represent-

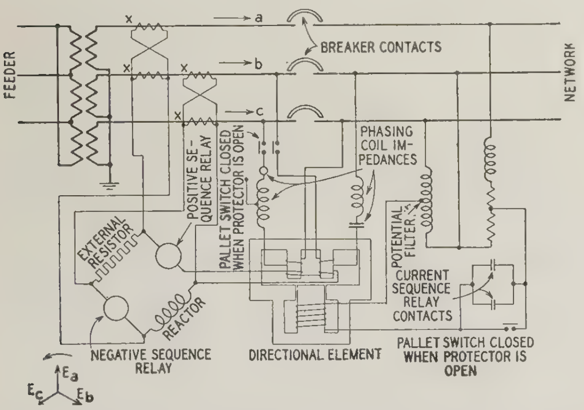


Fig. 3. Schematic diagram of a sequence relay for distribution networks

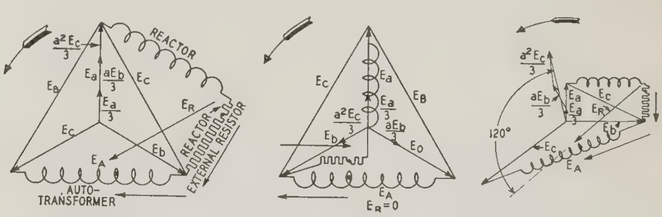
ing these unbalanced systems, chosen at random, indicate, as has been proved mathematically in other papers, that these filters will produce currents and voltages that are proportional to the positive or negative phase sequence quantities existing in the system from which they are energized. The series impedance of the voltage filter and potential coil is designed so that these elements can be combined to obtain the sensitive watt characteristic needed in the directional element.

The dual sensitive, non-sensitive relay characteristic is obtained by the combined operation of the directional element and overcurrent elements. Parallel connection of the positive and negative phase sequence current element contacts in the potential coil circuit serves to deënergize the potential coil during normal conditions. Operation of the directional element for the tripping function is initiated by action of either or both of the overcurrent elements. A short time delay is obtained between closure of the current element and directional element contacts, since this contact is held open by spring tension. This interval need be no greater than the operating time of present network relays, yet serves to prevent tripping the protector by sudden applications of load on the secondary network.

By setting the positive phase sequence element to pick up at currents up to 100 per cent of protector rating, balanced power reversals of that magnitude can be permitted. Negative phase sequence current settings are made relatively low so that sensitive operation of the directional element can be initiated by small magnitudes of negative phase sequence current.

It is of importance to note that sensitive operation of this relay may be obtained at all times by permanently closing the contacts of either or both current elements, if the insensitive reverse current characteristic is not needed and a negative phase sequence current source is not readily available. When this is done, the relay functions as a sensitive positive phase sequence directional element and can be used to replace the present sensitive relay.

In order to obtain a clear picture of the relay operation, it may be assumed that balanced 3-phase power is being fed in the reverse direction through the protector. All pallet switches in Fig. 3 are open since the protector is closed. The potential coil of the directional element is deënergized and the relay trip contacts are held open by spring tension, as negative phase sequence current is not present and the positive phase sequence current is not of sufficient magnitude to close the current element contacts. Now assume an assymetrical fault in the network, similar to that shown in Figs. 6 and 10. The moment the fault occurs, positive and negative phase



Figs. 4, 5, and 6. Diagrams of positive phase sequence voltage (left), negative phase sequence voltage (middle), and unbalanced voltage (right)

sequence currents appear in sufficient magnitude to close the sequence element contacts, energizing the potential coil. Since the fault is in the network the directional element tends to swing its contacts toward the closed position and tripping of the protector is thus prevented. Had the fault occurred in the feeder cables, operation would have been the same

except the relay contacts would have swung from the closed to the trip position and opened the protector.

Phasing Circuit

The phasing characteristic illustrated in Fig. 1 will prevent pumping of non-sensitive relays on low voltage distribution networks and is sufficiently limiting in its operating range to be satisfactory for many sensitive relay applications. In addition to checking the magnitude and phase position of the feeder voltage, the relay will not close if any of the feeder cables are interchanged and energized.

The phasing circuit consists of 2 separate coils of high impedance mounted separately over the directional element current coils. One coil is connected in series with a saturating reactor and capacitor across the circuit breaker contacts in phase *B*. This circuit is near resonance during normal conditions to provide ample torque for low phasing voltages. The second coil is connected across the phase *C* breaker contacts in series with a tapped reactor and a phasing lamp. The phase angles of these circuits are such that the currents in the 2 circuits are approximately 180 deg out of phase under normal voltage conditions. The resulting field of flux is as in a conventional circuit. When excited with high voltages, as encountered during cross phase conditions, the impedances increase to limit the current, and phase angles change so as to obtain opening torque and prevent damaging the protector by faulty closing. Vector diagram, Fig. 11, illustrates the operation of this circuit.

The tap on the phase *C* reactor serves to shift the relay closing curve, as indicated in Fig. 1, to prevent

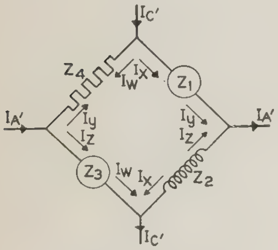


Fig. 7. Current filter

$$Z_1 = Z_3$$
$$Z_1 + Z_4 = (Z_2 + Z_3)\epsilon^{-j50}$$
$$I_{C'} = I_b - I_a = I_w + I_x$$
$$I_{A'} = I_c - I_b = I_y + I_z$$
$$\left.\begin{matrix} I_a \\ I_b \\ I_c \end{matrix}\right\} = \text{Line currents}$$

$$I_w = \frac{I_{C'}}{\sqrt{3}}\epsilon^{j30} \qquad I_y = \frac{I_{A'}}{\sqrt{3}}\epsilon^{j30}$$

$$I_x = \frac{I_{C'}}{\sqrt{3}}\epsilon^{-j30} \qquad I_z = \frac{I_{A'}}{\sqrt{3}}\epsilon^{-j30}$$

pumping if the system impedance angle will not permit use of the lagging closing curve.

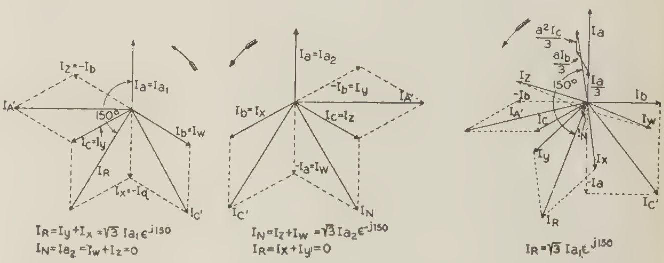
Operating Experience

Ten experimental relays, with the current element contacts connected directly in the trip circuit rather than in the potential coil circuit as just described, were mounted on 500-amp network protectors and installed on a 13.8-kv feeder of the United Electric Light & Power Company's system, April 11, 1931. All transformer banks connected to the feeder, which was 2.8 miles long, were of 150-kva rated capacity.

A general comparison of the operations of network protectors equipped with these sequence relays with the operations of protectors equipped with standard insensitive network relays installed previously at the same locations showed that the operations were reduced on the average only 40 per cent.

On blocking open the negative phase sequence current element contacts, it was found that further reductions in operations on the average of 90 per cent were obtained. The settings of negative phase sequence current elements were subsequently increased from 5 per cent of the protector rating to 8 per cent. The positive phase sequence current element setting at 50 per cent of the protector rating was not changed. While an improvement in the operation of the relays was affected, the results were not satisfactory.

From observations made, it was found that the current elements were causing the protectors to trip on suddenly applied secondary loads when the directional element trip contacts were held closed by power reversals. It should be remembered that the contacts of the current elements, in these experimental relays, were in series with the "trip" contacts of the directional element. Thus on the occurrence of an unbalanced secondary load, the negative phase sequence current element picked up, and since the



Figs. 8, 9, and 10. Diagrams of positive phase sequence current (left), negative phase sequence current (middle), and unbalanced current (right)

directional element "trip" contacts were closed by the reverse power flow, the protector opened. The current elements, which are practically instantaneous, picked up before the directional element, which tended to close on the secondary load had time to open its "trip" contacts, thus completed the trip-circuit. Large unbalanced secondary loads suddenly applied produced similar operations with the positive phase sequence current element picking up.

To remedy this condition, the contacts of the current elements of the 10 sequence relays were connected in series with the potential coil of the directional element as shown in Fig. 3. With this arrangement, the directional element "trip" contacts were normally opened and thus when either of the current elements picked up on a secondary load, the "trip" circuit could not be completed, as the disk of the directional element tended to rotate further in the "close" direction.

The network protectors equipped with these experimental sequence relays have been used at several other locations, since their initial installation, in order to obtain operating experience under all possi-

Table I—Operating Record of Protectors

Feeder Voltage (Kv)	Period (Days)	Total Operations for Period	Average Operations per Day
13.8	262	21	0.08
13.8	135	64	0.50
13.8	173	10	0.06
13.8	175	24	0.14
13.8*	124	207	1.70
13.8	168	20	0.12
13.8	108	49	0.50
13.8	265	7	0.03
3.0	179	1	0.006

*Graphic meter records have shown that frequent power reversals of long duration occurred at this location. Current magnitudes in excess of the relay settings caused the large number of operations noted. These operations have been practically eliminated by readjusting the current elements so that they do not pick up on the current magnitudes normally encountered at this location.

ble system conditions. Locations were selected where frequent and large reversals of power occurred due to elevator regeneration or other conditions. Satisfactory operation of all protectors was experienced at every location.

The operating record of the protectors in service at the end of 1932 is tabulated in Table I. The list includes all operations due to cable faults, interruption of the feeder at its source, and power reversals in excess of relay settings.

Twenty-nine faults have been experienced on feeders on which network protectors equipped with sequence relays were installed. The operation of the sequence relays on each fault was correct. Subsequently, several 1,600-amp and 3,000-amp network protectors equipped with sequence relays were installed.

Tests

Several tests were made to determine the ease with which the 10 protectors equipped with sequence relays could be opened after deënergizing the 13.8-kv feeder at the power station. These tests were made on the initial installation when all protectors were connected on one feeder.

Two methods of creating a negative phase sequence current were used:

1. A single-phase load on the secondary side of one distribution transformer bank.
2. Grounding one conductor of the 13.8-kv feeder at the station which causes an unbalance in the charging current.

Using a load connected from C phase to ground on the secondary side of 150-kva distribution transformer bank, it was found that a load of approximately 500 amp at 85 deg, or 5.2 kw, was required to open the 10 protectors on the feeder. Inspection made after the station breaker was opened but before the secondary load was applied showed that no protectors opened previous to applying the load. At the time of the above test, the negative phase sequence current relays were set to pick up at approximately 5 per cent of the protector rating and the positive phase sequence current relays were set to pick up at 30 per cent.

To open 10 500 amp network protectors equipped with the standard network relays set 30 per cent insensitive would require a load of 540 kw.

With the protectors originally closed and the station breaker open, all protectors tripped when a ground was applied to the A phase of the 13.8-kv feeder at the generating station.

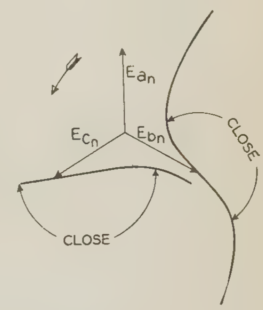
Repeating the test with all protectors blocked closed, the negative phase sequence current was measured at one location. It was found to be only 2.9 per cent of the protector rating instead of the 5 per cent required to operate the negative sequence current relay. Further tests indicated that a few protectors were tripped during the preceding test, by power exchanges through the feeder between portions of the network which were not connected on the low voltage side at that time. The remaining protectors cascaded open.

By switching operations at the generating station, 5 more miles of 13.8-kv cable were added to the feeder without increasing the connected transformer capacity.

After blocking the protectors closed and grounding the A phase of this longer feeder, the negative phase

Fig. 11. Operating characteristics of the separate phasing coil circuits

Closing torque is developed within a given circuit when the associated feeder voltage terminates within its closing area. The resultant torque is always in the "opening" direction when feeder cables have been incorrectly connected as indicated below:



DELTA-STAR SYSTEMS

Feeder cables interchanged	Feeder voltage E_b 180° from	Feeder voltage E_c 180° from	Direction of torque Phase B	Direction of torque Phase C
a and b	E_{a_n}	E_{c_n}	Strong open	Strong open
b and c	E_{c_n}	E_{b_n}	Light closing	Strong open
a and c	E_{b_n}	E_{a_n}	Strong open	Fair closing

With all cables rotated 120 deg or 240 deg both phases will produce opening torque.
If feeder voltage E_a = 0, the protector cannot close as the control circuit is connected across phase A-C.

STAR-STAR SYSTEMS

When any 2 feeder cables, other than phase *a* and ground, are interchanged and when all cables are rotated 120 deg in either direction, opening torques will be developed in the relay. When phase *a* and ground cables are interchanged, the low control voltage obtained prevents closing of the protector

sequence current was again measured at the above mentioned location and was found to be 8 per cent of the protector rating, which was ample to operate all negative phase sequence current relays.

Back feed tests on the long 13.8-kv feeder showed that all protectors other than those feeding back remained open and the relays had strong opening torques. Transformer voltages on some protectors as high as 133 volts were obtained during this test.

Complete laboratory tests and operating experi-

ence have shown that needless protector operations are practically eliminated by use of this relay. Decreased likelihood of light flicker and reduced wear on the protector result from keeping protectors closed a greater proportion of time than heretofore. Load-back methods of clearing feeders, equipped with insensitive relays, and the resulting disturbances in the network also are avoided. These advantages have been obtained in a single relay, without sacrificing the accurate phasing and tripping characteristics now considered essential to the successful operation of the network protectors.

Sequence Principles Used for Network Relaying

The application of phase sequence principles to the relaying of low voltage a-c distribution networks is described in this article, which is a companion article to that by H. S. Orcutt and M. A. Bostwick in this issue. The fundamental principles upon which this type of relaying operates are presented herewith.

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AN IMPROVED network relaying system has been developed utilizing a conventional single-phase relaying element and contactor type overcurrent elements excited by symmetrical phase sequence components to represent completely power flow conditions and control protector operation on a 3-phase 4-wire secondary network system. The principal problem that has arisen from the development of the low voltage a-c network with multiple supplies from several sources is that of preventing the excessive number of network protector operations that result from power interchanges between feeders through the network. In an endeavor to produce a network relaying system that would meet the requirements of the original relay specifications and in addition permit the flow of reverse energy encountered in normal operation, phase sequence currents and voltages have been utilized in the new network relaying system. These single-phase symmetrical components of current and voltage replace the 3 line-to-neutral voltages and phase currents ordinarily used and completely indicate power flow conditions.

Symmetrical component quantities may be considered as the mathematician's conception of a polyphase system; however, the quantities concerned are real, not imaginary, and are amenable to actual measurement. Phase sequence segregating filters have been developed permitting the isolation of any or all of the phase sequence currents and voltages, and may be applied to conventional elements to secure metering or relaying functions in response to changes in sequence quantities.

Essentially full text of "Application of Phase Sequence Principles to Relaying of Low-Voltage Secondary Networks" (No. 33-16) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

Network Relay Requirements

A review of network relay requirements, embracing application to systems employing low voltage and high voltage feeders from segregated substations and generating sources, feeding into a general network supplemented by spot networks, indicates the necessity for:

1. A master directional element to indicate direction of power flow.
2. Phasing features to control protector closing.
3. Selective tripping features in the relaying system to prevent opening of the protector upon reversal of energy through the switch during normal system operation with the feeder breaker connected to the source.
4. Sensitive tripping when the feeder is disconnected by the opening of the generating or substation breaker.

These requirements are fulfilled by the new relay system.

The master directional element consists of a single-phase watt relay operating on positive phase sequence voltage and current. This element is responsive to the direction of flow of positive phase sequence power under all conditions (Fig. 1). To be generally satisfactory from the standpoint of performing the phasing features the relay must:

1. Check phase sequence.
2. Check any interchange of phase wires on the supply feeder.
3. Connect the protector to the grid only when power will be fed from the feeder into the network.
4. Prevent any "pumping" of protectors, when the supply breaker is open and a defective unit remains in the closed position, thus energizing the feeder from the network.
5. Permit closing on a dead network.

Obtaining Phasing Characteristics

Phasing is accomplished in the new relay by the use of voltage segregating filters and auxiliary wind-

ings on the watt relay used as a master directional element.

A voltage segregating filter of the positive phase sequence type when connected to a system of phase sequence *abc* delivers at its output terminals a voltage proportional, under all conditions, to the positive phase sequence voltage. If the supply voltage is balanced, the output of the network will be proportional to and bear a definite phase relationship to the line to neutral voltage. If for any reason, 2 phases are interchanged the supply system phase sequence (order of appearance of maximums) is changed from *abc* to *acb* and when impressed on a sequence segregating voltage filter designed to deliver positive phase sequence voltage with normal phase sequence *abc* the output of the network will be zero, if the supply is balanced. During phasing periods experience and test have shown that balanced voltage conditions exist on incoming feeder circuits although phase sequence may be incorrect. Certain progressive interchange of leads on the supply circuit gives rise to proper phase sequence *abc* but rotated 120 deg or 240 deg in the counter-clockwise direction with respect to normal network voltage. Under this condition the output of the network is normal but rotated 120 deg or 240 deg, respectively.

The fundamental characteristics of voltage sequence segregating filters in response to changes in phase sequence, polarity reversals, and phase advancement disclose the possibility of using phase sequence quantities to accomplish phasing functions. Obviously, single-phase representation of the selected quantity may be employed thus permitting the use of a single-phase relay to represent a polyphase system adequately.

Drawing on the experience gained with the present protector relaying scheme, it has been demonstrated that the phasing characteristics can be secured by adding to the upper or current poles of the watt type relay, phasing windings excited by voltage across the open switch. The potential or lower pole of the relay is excited by voltage from the secondary network. The network voltage is chosen as reference point as it is necessary to check the incoming feeder voltage in magnitude, phase position and sequence against that of the network, to insure proper operation.

Following the conventional design of relay elements "watt" and "phasing" characteristics can be secured on a single-element relay (see Fig. 2) by the use of:

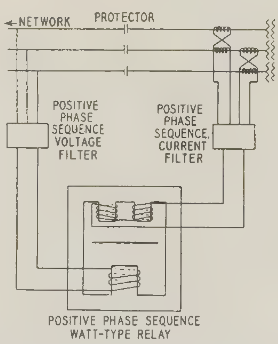
1. Positive phase sequence voltage and current for watt indication.
2. Network positive phase sequence voltage and the difference between network positive phase sequence voltage and incoming feeder positive phase sequence voltage (difference positive phase sequence voltage across the open protector) to perform phasing functions.

The combined phasing characteristic of the present *CN*-3 master relay and the *CNA* phasing relay is shown in Fig. 3, indicating that protector closure can occur only in a rather limited range due to the combined phasing features of both relays.

In utilizing phase sequence quantities to develop a relay with settings 10 to 100 per cent of transformer rating, it is not necessary to confine the "closing region" to the limited range employed in the present standard equipment but it may be extended to embrace *leading* voltages lower in magnitude than the network voltage. In actual practise these voltages occur very infrequently as incoming feeder voltage is high and leading, not low and leading.

To prevent "pumping" of protectors on systems employing high voltage underground feeders the phasing characteristics must be such that the relay contacts will not close when the incoming voltage is high and lagging indicating a "closed" protector exciting the capacitance of the cable from the network, with consequent voltage rise across the secondary mesh and network transformer. Mathematical analysis, field tests, and a check on the performance of existing relays indicate that to avoid pumping conditions the closing characteristic of the network relay as a phasing device, must be rotated through approximately 60 to 70 deg from the horizontal, as shown in Fig. 4. While linear closing characteristic of this nature would be excellent for a non-sensitive type relay, a study of Fig. 4 will show that the linear characteristic intersects the voltage Ec_1 and would permit protector closure due to cyclic rotation of conductors that produced normal phase sequence *abc* but advanced counter-clockwise 120 deg with respect to the reference or secondary network voltage.

The phasing voltages encountered in normal system operation are relatively small, having a magnitude of only a few volts. Under the conditions outlined above, the phasing voltage would approximate in magnitude the line-to-line voltages E_p, Fig. 4, which is many times the normal phasing voltage. It is desirable to have the phasing characteristic linear in the range of normal phasing voltages, but to deviate therefrom at higher values so as to avoid possible improper operation, under



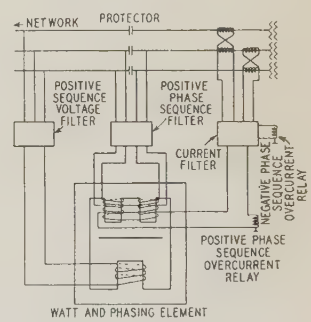


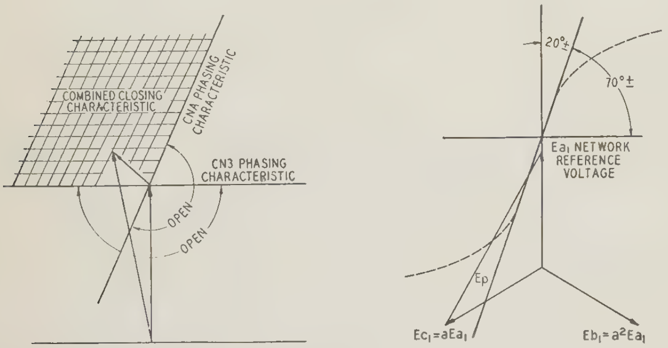
Fig. 1 (left). Master directional element of sequence relay

Fig. 2 (right). Diagram showing method of securing watt and phasing characteristics on the main element

certain system conditions that are a function of system repair and extension involving the human element.

It is recognized that the slope of the closing characteristic may be changed by governing the relationships between the flux on the upper and lower pole of the relay, for any one given condition. This can be accomplished by changing the phase angle of the

phasing current with respect to the phasing voltage. Any factor that decreases the phase angle of current to voltage in the phasing circuit rotates the closing characteristic in a clockwise direction. But it is necessary to have the closing characteristic in the vicinity of the normal value of reference voltage approximately 60 to 70 deg from the horizontal to prevent pumping; therefore, the normal angle of current to voltage is set by that requirement. However, the range of phasing voltages is very large and devices can be added to the phasing circuit, of the saturating type or of the form that produces resistance changes with current flow such as the conventional phasing lamp. With normal phasing voltages



Figs. 3 (left) and 4 (right). Phasing and closing characteristics of sequence relay

saturation effects and resistance changes do not occur and the phasing characteristic is linear. With increasing phasing voltages these changes occur and the ratio of reactance to resistance varies, resulting in change in the angle between phasing coil currents and voltage, causing a deviation from a straight line in the phasing characteristic as shown dotted in Fig. 4. The changing characteristics of the phasing circuit, with increased phasing voltages must be such that the characteristic curve does not intersect a voltage vector of normal magnitude rotated 120 deg counter-clockwise to prevent false closure in event of accidental cyclic rotation of conductors during cable splicing producing a 120 deg shift of positive phase sequence voltage. The changing characteristics on the upper part of the phasing curve encroaches upon the possible range of back feed voltages existing due to a single "closed" protector on systems supplied by underground high voltage cables. Analytical work and field tests indicate that the proposed curve is sufficiently broad in its characteristics to perform satisfactorily on existing and proposed systems employing 13-kv and 27-kv feeder circuits.

Obtaining Selective and Sensitive Tripping

Selective and sensitive tripping is obtained by the combined operation of the master directional element and current magnitude relays. Selective tripping refers to relay operation with balanced reverse power flow and would be above the range produced by the inherent system conditions during normal operations. This feature reproduces the results obtained from present network relays when increased reverse power settings are used.

The current magnitude relay used for selective tripping is a simple single-phase contactor type relay energized by positive phase sequence current. When positive phase sequence current of sufficient magnitude has closed the contacts of this relay, the potential coil of the master directional relay is energized and tripping of the protector occurs if the power flow is from the network to the feeder.

Sensitive tripping refers to relay operation at times when the supply breaker is open. A current magnitude relay energized by the negative phase sequence component of the line current and operating in a manner similar to the relay used for selective tripping provides for sensitive tripping. A current segregating filter provides the symmetrical components of line current.

Negative phase sequence current does not exist in a perfectly balanced polyphase system. In the practical low voltage network system under normal operation negative phase sequence current exists only in very minor quantities. However, every unbalanced load or fault acts as a source of negative phase sequence voltage and current transforming or converting from positive phase to negative phase sequence order. The same considerations apply to zero sequence quantities if the system or mesh is grounded. We thus have a quantity which is absent normally but is available under abnormal conditions to provide a discriminating means whereby tripping functions may be initiated. Therefore, if the selective tripping combination is supplemented by a negative phase sequence overcurrent relay, tripping of the protector can be limited to fault or reverse unbalanced conditions on the high voltage feeder.

The appearance of negative phase sequence current, at a time when positive phase sequence power is from the grid to the feeder, indicates abnormal conditions such as a primary fault or primary load unbalance and warrants protector opening. The negative phase sequence current element can be set at low values since only small quantities of negative phase sequence current are normally present in the system.

Since the sensitive tripping arrangement provides for clearing the protector in case of faults, it would appear that the selective tripping feature is unnecessary except for the condition of a 3-phase balanced feeder fault or to avoid damage to individual protectors from over-loading during abnormal system conditions not identified with any particular feeder. Field experience may show that the selective tripping arrangement can be eliminated.

Clearing Protectors for Inspection

While tripping functions therefore are provided for all types of primary faults and eliminated for all secondary faults, provision must be made for clearing of the protectors for inspection or construction purposes. This is accomplished by providing a source

of negative phase sequence current. A small induction-synchronous motor-generator set arranged as in Fig. 5 and connected to the feeder at the generating source after opening the feeder breaker may be used. The voltage required will be relatively low as only small values of negative phase sequence current are required and the impedance to the flow of negative phase sequence current is the short-circuit impedance of the negative phase sequence mesh. Thus the kilovoltampere capacity of equipment required and the current flow during operation will be so low that voltage disturbance will not result on the secondary network.

In stations equipped with ground and test bus, the motor-generator set can be connected to it through suitable transformers and without starting apparatus.

The majority of transformers used in network distribution are delta connected on the primary winding, and the neutral of the feeder circuit usually is established at the generating station. Upon opening of the feeder breaker the feeder circuit is ungrounded and negative phase sequence current can be produced by earthing one conductor of the delta connected circuit, which effectively short-circuits out the capacitance of that conductor and increases the voltage on the capacitance to ground of the other conductors. This is equivalent to loading of 2 phases only, thus creating a load unbalance and giving rise to negative sequence current. The magnitude of current will depend upon capacitance and thus upon the type, length, and voltage of the circuit involved. Higher-voltage underground cable circuits, 13 kv and above, will be most effective in producing negative sequence current when one conductor is earthed.

Any type of apparatus that places an unbalanced load between phases produces negative sequence current and any simple loading device can be employed. Phase-to-phase loading is preferable to phase-to-ground loading. Apparatus for the generation of negative phase sequence current may be located in the high voltage circuit at the generating station or in the low voltage network on the transformer side of a single protector per feeder.

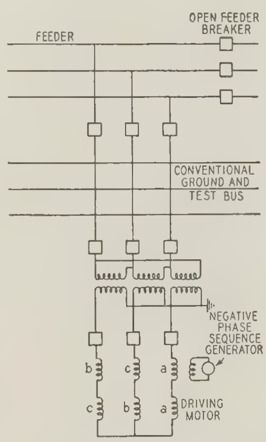
Combination Sequence Segregating Filter

The determination of a given phase sequence current requires that the remaining 2 current components be eliminated, that is, not passed through the meter element. In 3-phase ungrounded operation, zero phase sequence currents are not present and are automatically eliminated. In grounded neutral systems zero phase sequence current is present and means must be provided to eliminate the possibility of its appearance in the relay element.

Fundamentally, zero sequence currents in the 3 line conductors are equal and in phase. If cross-connected current transformers are used, as shown in Fig. 6, for the supply to a sequence segregating filter, the output of the 2 current transformers will not contain zero sequence currents. Inasmuch as the output of the 2 current transformers is the difference between the 2 phase currents the zero phase sequence current is automatically canceled and the output contains only positive and negative phase sequence current.

Equations may be derived which show that a current proportional to positive or negative phase sequence current can be secured by adding suitable components of current IA' and IC' (see Fig. 6) and passing the resultant through a suitable metering element. Inasmuch as only fractional portions of the A' and C' currents are added to produce either positive or negative phase sequence currents it is obvious that parallel branch or bridge type filters are required. Such a filter is shown in Fig. 6.

A combination filter is thus produced that permits



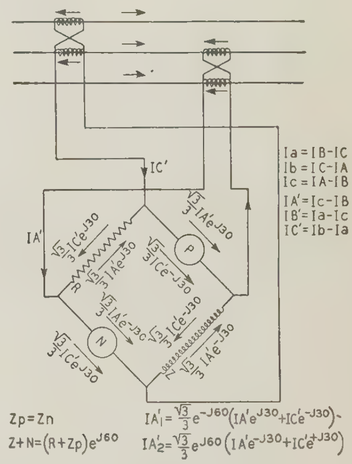


Fig. 5 (left). Connections of a small induction-synchronous motor-generator set used as a source of negative phase sequence current

Fig. 6 (right). Combination current filter to indicate positive and negative phase sequence currents

simultaneous indication of currents proportional to positive and negative sequence currents in the leads of the supply circuits. The elements P and N may be any form of relaying or indicating apparatus providing the fundamental relationship of $Z_s + Z_n = (R + Z_p)e^{j60}$ is maintained. The magnitude of positive or negative phase sequence current indicated in branches P and N, respectively, is $\sqrt{3}$ times the actual sequence component in the line conductor and is displaced by 150 or 30 deg depending upon physical connections. In relaying or metering circuits both magnitude and angular relationship must be properly related to secure proper indications.

Network relays designed in accordance with the general theory described in this article have been constructed and are now in operation on the system of the United Electric Light and Power Company in New York City. The satisfactory performance of the relays in the most severe type of service that could be selected within the system, indicates the adequacy of the fundamental principles and subsequent relay design. The general features of relay design and operating experience are outlined in the companion article "A Sequence Relay for Network Protectors."

Automatic Train Control

TRAIN CONTROL systems which automatically limit railway trains to prearranged speeds, and which are operated by conditions existing on the track ahead of the train, have been installed on many railroads in the last few years. The systems used are of 2 general types, the intermittent type and the continuous type. Brief descriptions of these systems are given in the 3 sections of the article presented herewith. The first section presents a general description of the 2 types of automatic train control, particularly as applied by the Illinois Central Railroad Company. The second section contains details of the intermittent type of control applied by the Baltimore and Ohio Railroad Company; and the third section is a brief description of the 2 forms of the continuous type of control applied by the Reading Company.

I—Two Types of Automatic Train Control

A general description of automatic train control including the salient features of the 2 general types of control most frequently used is given in the following excerpts from "Railroad Signaling and Train Control" by R. B. Amsden and W. M. Vandersluis, both of the Illinois Central Railroad Company, Chicago, Ill.:

Every successful scheme of automatically applying the brakes to stop or control the speed of a train is based upon the fact that opening of the air brake pipe line results in application of the brakes. Two orders of the Interstate Commerce Commission, issued June 13, 1922 and January 14, 1924, respectively, and subsequently modified so that an engineman, if alert, may forestall the brake application and proceed without stopping, required certain railroads to select and install the type which each considered most suitable for its particular conditions, in accordance with specifications and requirements prescribed by the commission.

Every type of train control device requires a roadside element designed to coact with an engine-carried element so as to transmit to the locomotive the conditions existing on the track as would be indicated by a modern automatic signal system. After the information is conveyed to the engineman, it may be used either to apply the brakes or to indicate by means of a cab signal, visible or audible, the conditions which exist. The devices may be classified in 2 general groups, the intermittent and the continuous. The intermittent may be further subdivided into the contact type and the non-contact type. The contact type depends for its operation on a physical contact between the train element and the roadside element while the non-contact type depends on an electrical or magnetic impulse without physical contact between the train element and the roadside element.

The trend has been decidedly toward the induction type of equipment and no installations of the contact type have been made on any road except the 3 which had such installations at the time the orders were issued. One of these subsequently changed to the induction type.

Intermittent System

The intermittent type of device receives its control at certain fixed points along the roadside, usually at or near a signal, and is incapable of reflecting any change in track conditions between any 2 of the indicating points. It is an adjunct to the automatic block signal system for the purpose of preventing that class of accidents which are due to the failure of employees to observe, understand, or obey signal indications. Most of the intermittent induction types in service employ an inert roadside element consisting of a laminated core upon which are mounted coils, the terminals of which are connected through a relay of the signal system. No energy is required for the track element.

The locomotive receiver carries 2 coils mounted on a laminated core, both of which are energized by direct current from the headlight generator. Associated with these are a number of circuits and relays on the locomotive which provide a means for producing a brake application. In all the variations of this type, the brake application is initiated by a sudden reduction of current flow in the main locomotive relay which is produced by the action of the receiver passing over the track inductor when the circuit of that inductor is open through the roadside relay in the stop position.

Continuous System

The basis of the continuous train control systems which have been developed, is the inductive fields produced by alternating current flowing in the rails. Collecting coils are mounted on the locomotive so as to move in the field produced around the rail. The current which is induced in these coils is transmitted to amplifying apparatus on the locomotive. The amplified current in turn controls the circuits that operate electropneumatic valves directly controlling the brakepipe pressure. Circuits also are provided for a visible cab signal which constantly shows the conditions of the track. Any change in conditions in a clear block, which calls for a reduction in speed, is immediately reflected by a corresponding indication in the cab. The brakes also are applied unless properly forestalled by the engineman. Conversely,

From "Railroad Signaling and Train Control" (No. 33-8) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933. Full text of that portion of the paper which describes automatic train control is presented herein.

a more favorable condition in a block is immediately transmitted to the engineman and the train does not have to move under restricted speed until the next signal is reached.

The continuous type of device functions on a closed circuit, which is the basic principle of signaling, failure on any part causing a stop application. It may be used with or without permissive signals on the roadside, and 4 railroads are demonstrating the practicability of operating without roadside permissive signals. The addition of a centrifugal governor, usually applied to the forward pony truck axle of the locomotive, provides for the automatic control of the train at the varying speeds required by different track conditions.

Alternating current of 100-cycle frequency is favored for use in the rail circuits to avoid possible interference from commercial power sources. To provide 4 cab indications and maximum protection against inductive interference from other circuits, a specially designed code transmitter may be used in connection with the roadside apparatus, consisting of a constant speed induction motor geared to a shaft carrying "coding" cams which operate contacts to interrupt the 100-cycle alternating current. Code frequencies of 80, 120, or 180 interruptions per minute for the approach, approach restricting, or clear indications, respectively, are impressed upon the track, depending upon the condition of the track in advance. The engine equipment is designed so as to respond only to the track current frequency when it is interrupted at the proper rate. Absence of current in the rails gives the stop indication.

Operating officers and enginemen report the safety features in cab signaling, which make it independent of fogs, storms, or other obstructions to vision, as one of the greatest advantages of train control.

The first orders of the commission having accomplished their purpose of promoting extensive development of automatic train control, an order was issued on November 27, 1928, to the effect that the railroads would not be required by order to install any more train control at present but that they are "in no way relieved from the responsibility which rests upon them to provide additional protection when needed in territory now protected by automatic signals." This leaves the roads free to use train control, cab signals, or such other means as they may see fit, to secure additional protection, particularly on dense traffic lines.

II—Intermittent Type of Control on the B. & O.

A description of the intermittent type of automatic train control, known as the intermittent inductive auto-manual train stop system, is given in the following excerpts from "Centralized Traffic Control and Train Control on the Baltimore and Ohio Railroad" by J. H. Davis and G. H. Dryden, both of the Baltimore and Ohio Railroad Company, Baltimore, Md.:

Orders of the Interstate Commerce Commission issued in 1922 and shortly thereafter required 47 railroads each to make an installation of automatic train control on 2 passenger locomotive divisions, and 47 other railroads were required to install control on 1 division, thus involving a total of 94 roads and 141 passenger locomotive divisions. As The Baltimore and Ohio Railroad was affected by the commission's order to the extent of 2 divisions, it became necessary to investigate the principal systems offered at this time and select the one best adapted to its requirements. The territory first proposed and later approved by the commission was from Baltimore, Md., to Washington, D. C. Although the distance between these 2 cities is only 34.6 miles, yet due to the very heavy passenger traffic, it was thought that this territory would offer a severe and thorough test in performance and capacity for any system.

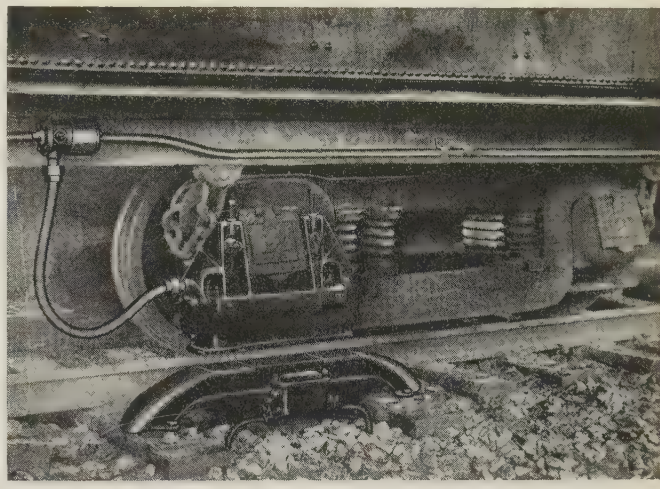


Fig. 1. Locomotive receiver over wayside inductor

It was essential that a system should be chosen which would not only meet the commission's requirements, but one which would not reduce the capacity of the line. After much detail study recommendation was made that the "intermittent inductive auto-manual train stop system" be installed, not only between Baltimore and Washington but also between Baltimore Md., and Philadelphia, Pa., a distance of 92.5 miles, to meet the requirements in the second order of the Commission.

Description of the System

This train stop system is superposed on the automatic block signal system. The block signal system makes use of the track rails in combination with relays and insulated joints dividing the trackway into blocks. A potential is impressed across the rails at the leaving end of the block, the rails being bonded into a conductively continuous circuit

From "Centralized Traffic Control and Train Control of the Baltimore and Ohio Railroad" (No. 33-9) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933. Full text of that portion of the paper which described automatic train control is presented herein.

to the entering end. A translating device such as a relay responding to low potentials is located at the entering end, and controls the indications of a wayside signal installed at that point. When the track rails are continuous and the trackway is unoccupied, the relay at the entering end of the block will be energized, thus transmitting such indication to the wayside signal, permitting an oncoming train to run with unlimited speed in so far as occupancy of the particular track is concerned. By overlapping the control, the signal indicates the condition of 2 successive blocks. Thus if the 2 blocks ahead are clear the signal will show the indication "proceed with speed," while if only one block in advance is clear, the indication displayed is "prepare to stop at the next signal." This indication is usually termed the caution one. When the block immediately beyond a given wayside signal is occupied or its rails are broken or other hazardous conditions obtain therein, the signal at that location displays "stop and proceed, prepared to stop on vision." The observance of these restrictive wayside signal indications is enforced by means of the auto-manual train stop system.

The auto-manual train stop system consists of 2 distinct parts: the locomotive equipment, and the wayside equipment. The wayside equipment is a device known as an inductor, which is located approximately 70 ft in front of each block signal governing the entrance to a block in the direction from which the signal is approached and is placed just outside the right-hand rail. Although this inductor is electrically connected to its signal by 2 insulated wires, it normally carries no current. It consists of a U-shaped magnet with laminated cores, large pole

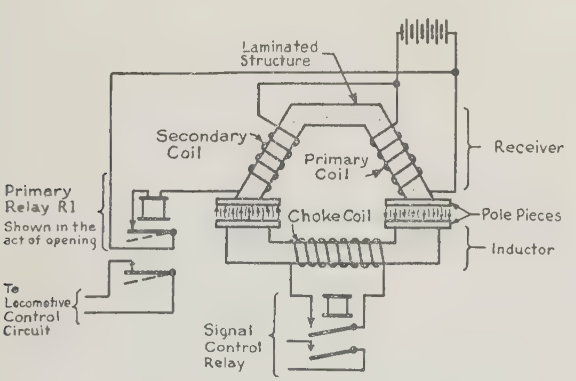


Fig. 2. Circuit showing principles of control, wayside to locomotive

pieces, and a coil which is connected to the front contacts of the signal control relay located at the base of the wayside block signal.

The locomotive equipment consists of a receiver, a group of relays, electropneumatic valve, an actuator, a forestalling device, and a reset contactor. The receiver is mounted on the right side of the forward tender truck of the locomotive in such a location as to pass 2 in. above and directly over the inductor. There is no physical contact between the two. This device is an inverted U-shaped magnet with laminated cores and large pole pieces. It carries 2 coils, which are called the primary and secondary coils. Its general appearance is shown in Fig. 1.

The relay group is contained in a spring-mounted housing located on the deck of the tender tank. Its functions will be described later. The electropneumatic valve is located in the cab. It takes energy from the relay group and controls the brake-valve actuator. A brake-valve actuator is used to rotate the engineman's brake valve to the service position when an automatic application of the brakes is made. An acknowledging contactor located in the cab is used to forestall an automatic brake application by manually operating its handle. A reset contactor is located on the side of the tender and is operated from the ground after the train has been brought to a complete stop.

Operation of the System

As the locomotive passes a wayside signal which is displaying a "caution" or a "stop" indication, its receiver passes over the inductor on open circuit (see Fig. 2). A surge of magnetic flux builds up in the secondary coil of the receiver and produces a momentary negative current in the relay. This negative current is sufficient to allow the relay to open, and when once open, stays open until restored, due to its being a "stick" relay. The opening of the primary relay deprives the electropneumatic valve of energy, which causes the valve to open and release the air from the larger piston of the actuator. The actuator, therefore, moves the brake valve to the service position which applies the brakes to the moving train.

The system is so arranged that the engineman can at all times operate his brake valve to the service or emergency position, but he cannot release the brakes manually during an automatic application. To restore the system to normal and release the brakes after they have been applied by the system, it is necessary for him to leave his seat and operate the reset contactor.

If the engineman is alert and fully capable of handling his train, he can forestall a brake application when passing a "caution" or "stop" signal indication by operating an acknowledging contactor located within easy reach of him in the cab. Under this condition a whistle sounds when the receiver passes over the inductor; when the whistle stops, it indicates that the acknowledging lever should be restored to normal position. He must, however, release the handle in 15 sec. If he held it for a longer period, the brakes would be applied automatically, but could be released after restoring the acknowledging contactor to the normal position.

When the train passes a wayside block signal which is displaying a "clear" indication, the coil of its inductor is on closed circuit. As a result, the receiver may pass over an inductor in the clear condition without a reduction of the primary relay's current intensity to the drop-away point. Therefore, the electropneumatic valve will remain energized and no brake application will be effected.

III—Continuous Types of Control on the Reading R.R.

Two forms of the continuous type of automatic train control are described briefly in the following excerpts from "Modern Signaling on the Reading Railroad" by E. W. Reich and G. I. Wright, both of the Reading Railroad, Philadelphia, Pa.:

Loop System of Train Control

The first installation of automatic train control on the Reading Railroad was made in 1925 on the Atlantic City Railroad (now Pennsylvania and Reading Seashore Railroad) covering a territory of 55 miles between Camden, N. J., and Atlantic City, N. J. The system installed is a continuous speed control with speeds of 85, 40, and 25 miles per hour imposed, together with a 3-indication cab signal indicating high, medium, or low speed. High speed or 85 miles per hour which is maximum permissive speed on this branch is imposed in clear blocks, medium speed of 40 miles per hour between a caution signal and braking point in approach of a stop signal and low or 25 miles per hour between this braking point and the stop signal and while passing through an occupied block.

In this system there is a 2-element train-control relay located on the locomotive, the track element being energized through what is known as an axle circuit. The secondary of the track transformer is connected across the rails at the receding end of track circuit, current flows through one rail toward the train in the circuit across wheels and axle of the locomotive to the opposite rail, thereby completing the circuit. The flow of this current in the rails induces a second current in a receiver on the front end of the locomotive mounted a few inches over the rails; this current is then passed through special power amplifier tubes and then to one element of the train control relay. The other element receives energy from a combination line and track circuit known as the loop circuit.

This loop circuit requires a special transformer connected through resistance coils to both rails of the track circuit, and the circuit is completed through a line wire running the entire length of the block which is connected to both rails of the track circuit at the opposite end. Current flowing in the loop circuit (through both rails in parallel and line return) is picked up by a second receiver mounted on the rear of the locomotive and through amplifiers energizes the local coils of the train control relay.

The 3-position train control relay assumes a vertical position when either or both of its control elements are deënergized, and is energized in a predetermined position when both elements have a current flow with a certain phase relation, and energized in the opposite position when current in one of the elements is reversed. This change of phase relation is accomplished through the pole changing of the line or loop circuit as the polarity of track elements is always constant. The polarity of the loop circuit is controlled through the position of a wayside signal controlled 2 blocks in advance of the one occupied, thereby coördinating train control and cab signaling with the wayside signal indication. The electro-pneumatic brake equipment and cab signals on the locomotive are actuated by local circuits controlled by the train control relay described above. The current for operating this local equipment is supplied from a special generator which also serves to furnish power for the electric headlight of the locomotive.

From "Modern Signaling on the Reading Railroad" (No. 33-21) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933. Full text of that portion of the paper which describes automatic train control is presented herein.

Continuous Code Type

The second installation of train control was made on the Behtlehem Branch in 1927, extending from Jenkintown, Pa., to Bethlehem, Pa., a distance of 46 route miles. The system installed is a continuous 2-speed code type with 4-indication cab signaling, a low speed of 20 miles per hour being imposed under certain track or block conditions. Unlike the loop system of train control previously described, where the train control relay was actuated from a combination of track and line circuits, the code system depends entirely on track or axle current. Code energy flows in one rail of track to the front wheels and axle of the locomotive returning to the transformer through the other rail. This flow of axle current induces a second current in receiver coils mounted on the locomotive ahead of the front wheels. The 2 receiver coils are electrically connected so that the voltages induced in them are additive when alternating current flows in opposite directions in the 2 rails. The circuit of receiver coils is tuned to resonance at 100 cycles and induced current passes through 2 stages of transformer coupled amplification to a master transformer and relay, which in turn actuates the several decoding relays tuned to a code frequency for the various cab signal indications and the pneumatic brake control.

Code is obtained from a small motor operated coder through which the various code frequencies are superimposed on the track circuit coördinated with the position of wayside signal equipment for 2 blocks in advance of the one occupied. Control codes are as given in Table I.

Table I—Control Codes

Frequency	Indication
180	Clear
120	Approach medium
80	Approach with imposed slow speed
0	Stop with imposed slow speed

It is characteristic of both the loop and code system of continuous train control that any change in conditions occurring at any time in the clear block immediately causes a change to a more restrictive signal in the cab or locomotive and functions to initiate an automatic application of the brakes. Conversely,

cab indication and control of automatic brake equipment are released immediately following any change in conditions ahead which would make a higher speed permissible.

The arrangement of pneumatic brake control necessitates that the engineman operate on acknowledging lever when a change to a more restrictive indication occurs. The engineman then has a 6-sec interval to initiate a reduction to the imposed speed that is permitted with the particular cab indication being displayed. Unless the engineman immediately acts to acknowledge and reduce speed, train control equipment will function and stop the train. With this form of pneumatic control it is impossible for an engineman to observe a restrictive indication at wayside signal in advance of the train, forestall the application of brakes, and proceed at an unauthorized speed.

Vapor Stream in Vacuum Arcs

A summary of the experiments showing the existence of a high velocity vapor stream issuing from the cathode region of a vacuum arc is presented in this article. Velocities obtained by different methods are given. The article includes a review of the theories proposed to account for the vapor stream. Several theories proposed are shown to be inadequate, the one possible theory being based upon the presence of multiply charged ions which leave the cathode after neutralization with a high velocity.

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IN THE last few years it has been discovered that a blast of vapor issues at high velocity from the cathode region of a vacuum arc. The consideration of this subject is important in the study of the arc. Previous theories of the cathode of an arc, which have not taken account of the vapor stream, must be extended, for the vapor blast, as it now appears, is a part of the cathode phenomena, and as such must be included in any satisfactory theory of the cathode of an arc. The energy carried away in the high velocity vapor stream, which is not an inconsiderable part of the total energy loss at the cathode, must be included in the heat balance at the cathode.

Full text of "High-Velocity Vapor Stream in the Vacuum Arc" (No. 33-20) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

By "vacuum arc" is meant an arc between metal electrodes in a residual gas at low pressure—a few microns or less. Such an arc burns, near the cathode at least, primarily in the vapor of the cathode material. Vapor of the cathode metal leaves the cathode region with a velocity over 10^6 cm/sec. Such velocities in themselves are not extraordinary, but in the arc their origin is a matter of wonder. The velocities correspond to equivalent volts of 36 to over 500—several times the total arc voltage—so that a direct electrical origin is not obvious. (The volt equivalent of the velocity of a particle is the potential through which a singly charged particle of the same mass must fall in order to acquire the same velocity; it is calculated from $eV = {}^1/_2\, mv^2$.) Several different methods of observation, described in this article, yield results of the same magnitude, however.

Experimental Results

The existence of the high velocity vapor stream was first discovered by Tanberg[1] who observed and measured a force of considerable magnitude on the cathode of a vacuum arc. A copper rod, suspended freely by a fine wire, as shown in Fig. 1, served as the cathode of the arc. Before the arc was drawn by moving the anode into contact with the cathode, the pressure in the vessel was about 0.2 micron; at the

1. For all numbered references, see list at end of article.

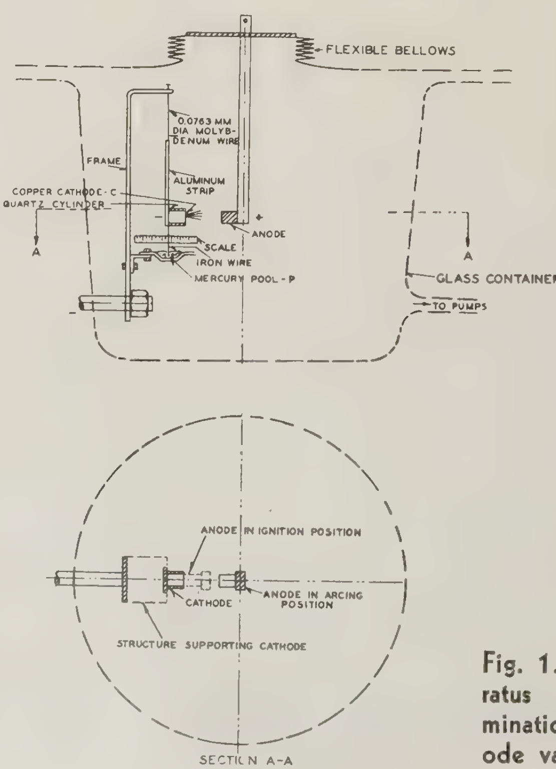

Fig. 1. Apparatus for determination of cathode vapor speed

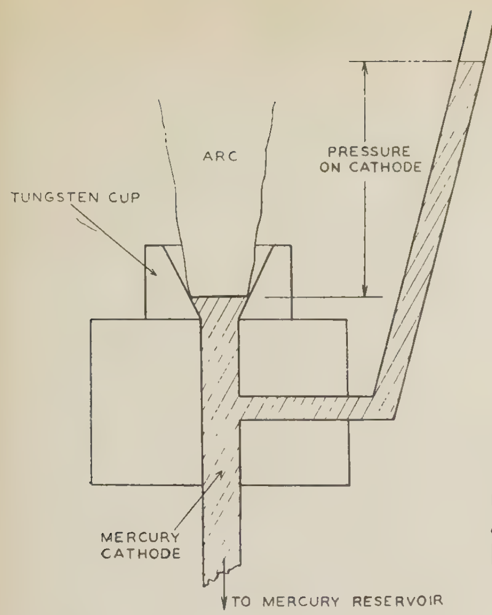

Fig. 2. Schematic diagram of apparatus used in Kobel's experiment

end of a test of a few seconds' duration, the pressure had increased to some 10 microns. When the arc was burning the reaction on the cathode caused a deflection of the whole cathode structure; from the length of support and the deflection, the force on the cathode was found. The cathode was weighed before and after a test of known duration so that the loss of weight per second was known. The force is equal to the change of momentum—the mass of vapor escaping per second times its mean velocity. The velocity determined in this way was 1.04×10^6 cm/sec, as the average of several tests.

By another method also, Tanberg measured the vapor velocity. A glass vane was suspended 2 cm before a fixed cathode. With an arc playing, the vapor issuing from the cathode caused the vane to deflect. From the vane deflection and the mass of copper vapor deposited on the vane per second, the mean velocity of the vapor striking the vane was found to be about 1.35×10^6 cm/sec.

Kobel[2] observed a large force at the cathode of a mercury arc, and in a similar way calculated a high velocity for the vapor leaving the cathode. The mercury level in a conical tungsten cup was adjusted until the cathode spot just covered the entire mercury surface. The difference in level of the mercury in the cathode cup and in a connecting side tube, shown schematically in Fig. 2, represented the force on the cathode. The loss of mercury from the cathode was measured by observing the rate of change of mercury level in the tungsten cup. From these 2 quantities the mean velocity of the vapor leaving the cathode region can be calculated. Values from 1.15 to 3.1×10^6 cm/sec are obtained, with an average of 2.24×10^6 cm/sec.

All of the results mentioned above were obtained from measurements of momentum, though the way in which the balancing force was read differed slightly. Berkey and Mason,[3] however, measured the *energy* of the vapor stream. The experimental arrangement is shown in Fig. 3. A silver vane was suspended in front of the cathode of a copper vacuum arc. To the side of the vane away from the cathode, a thermocouple was soldered. The thermocouple gave the rise in temperature during a period of arcing; from the rate of rise of the temperature and the thermal capacity of the vane the energy input to the vane was calculated. The mass of copper deposited on the vane was determined by weighing. These 2 quantities permitted the root mean square velocity of the vapor striking the vane to be calculated. The values

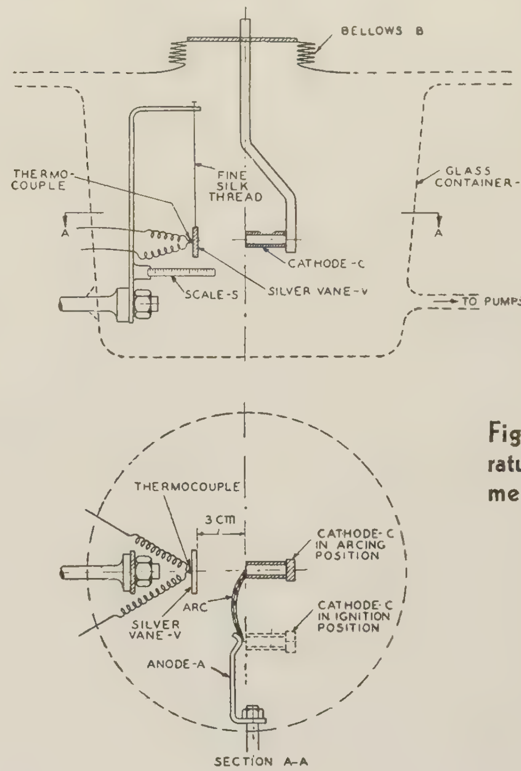

Fig. 3. Apparatus for measurements on cathode vapor stream

obtained lie between 1.74 and 2.46×10^6 cm/sec with an average of 2.04×10^6 cm/sec. The deflection of the vane was also obtained in these tests, and the mean velocity of the vapor calculated as 1.62 to 3.7×10^6 cm/sec, with not very great accuracy.

Sources of Error and Corrections

Several corrections have been made or considered in attempting to eliminate sources of error in measuring the vapor velocity. The most obvious, that of the electrodynamical force on the cathode resulting from the disposition of the current leads was estimated by Tanberg and deducted before the values of velocity given above were calculated. A further electrodynamic force, resulting from the convergence of current flow at the cathode spot, was estimated by Risch[4] to be not over 5 per cent of the measured force. The radiation pressure on the cathode was an entirely negligible factor. The reaction pressure of the electrons leaving the cathode was not over 5 per cent of the total force, as pointed out by Risch.[4] Thus, of the forces upon the cathode measured by Tanberg and Kobel not over about 10 per cent can be attributed to causes other than the reaction of the vapor leaving the cathode region.

None of the above mentioned corrections is applicable to the force on the vane suspended in front of the

Table I—Quantities in Vapor Stream Observed by Different Investigators

Observer	Arc	Method	Range of Data: Current, Amp	Range of Data: Force, Dynes	Range of Data: Mass Involved	Results—Average of Several Tests: Mean Velocity Cm/Sec	Results—Average of Several Tests: Equiv. Volts
Tanberg	Copper	Force on cathode	11 to 32	189 to 435	Avg 1.5×10^{-5} g/amp-sec	1.04×10^{6}	36
Tanberg	Copper	Force on vane	14 to 18	63 to 92	4.3 to 6.5×10^{-5} g/sec	1.35×10^{6}	60
Kobel	Mercury	Force on cathode	30 to 37	687 to 1,700	Avg 1.7×10^{-5} g/amp-sec	2.24×10^{6}	520
Berkey and Mason	Copper	Force on vane	20	36 to 70	2.22 to 2.38×10^{-5} g/sec	2.48×10^{6}	202
				Energy, Ergs/Sec		**Rms Velocity**	
Berkey and Mason	Copper	Energy imparted to vane	20	3.59 to 7.26×10^{7}	2.22 to 2.38×10^{-5} g/sec	2.04×10^{6}	137

arc. The mean velocity calculated for the vapor striking the vane can be in error only if the mass involved is incorrect—that is, if some of the vapor striking the vane is reflected without condensation. This seems hardly probable as metal vapors usually condense with little reflection. Furthermore, the amount of copper deposited on the vane was just the amount to be expected if a cosine distribution of the measured loss of material from the cathode existed; and the density of vapor deposited on the walls of the containing vessel followed a cosine law. No great amount of reflection thus seems reasonable. If such did occur, the root mean square velocity would be more nearly correct than the mean velocity; actually about the same values are secured for each.

The vane may receive energy from the arc, in addition to the energy of the impinging vapor, by radiation and by recombination of ions upon the vane. The radiation energy received was measured experimentally, found to be small, and was subtracted from the total before the root mean square velocity quoted was calculated. An upper limit to the latter energy would be obtained by considering all the vapor condensing as ionized. Then the energy of recombination would amount to less than 10 per cent of the total.

Other sources of error lie only in inherent difficulties in reading the experimental quantities. While the masses involved could be determined exactly, deflection methods probably permitted no great accuracy in determination of the forces; and Kobel records difficulty in adjusting the mercury levels. It is probable that the energy measurements yield more accurate values of the velocity of the vapor stream than the other methods.

Some of the quantities observed by the different investigators are given in Table I. The volt equivalent of the velocity is given in order to aid in explaining the theories offered. For the energy measurements this quantity may be calculated directly; but the mean velocities should be translated into root mean square velocities before calculating the volt equivalents. A knowledge of the velocity distribution would be necessary in order to get the ratio of root mean square to mean velocity; for a uniform velocity distribution the ratio is one, while for any other distribution the ratio is greater than one. Since the actual distribution is entirely unknown, the minimum value is the one used in the table.

Several theories have been put forward to account for the origin of the high velocity of the vapor. The temperature of the cathode spot is inadequate to give the emitted vapor the velocities calculated. The temperature of the cathode spot of the copper vacuum arc has been estimated to be under 3,000 deg K,[5] while in the mercury arc the cathode temperature is probably only a few hundred degrees. The vapor velocities, however, are the same magnitude as the average molecular velocity of a gas in thermal equilibrium at several hundred thousand degrees so that a purely thermal origin of the high speeds seems impossible.

Wellman's Theory

Wellman[6] suggested that, though the reaction of the copper leaving the cathode at 3,000 deg K was small, the reaction of gas evolved from the cathode during arcing might account for the remainder of the observed force. His calculations were based upon an incorrect value of current, however, so that the actual force of the gas is also a small factor. Furthermore, the mass involved in calculating the high velocities was determined by weighing the cathode before and after arcing so that any net loss of gas was included with loss of copper; only gas evolved during arcing and reabsorbed before the subsequent weighing of the cathode would not be discerned. In the mercury arc it seems unlikely that any gas was evolved from the cathode.

Compton's Theory

It has been shown by different methods[7,8] that positive ions drawn to an electrode by an electric field are neutralized but give up to the electrode only part of the kinetic energy acquired from the field; part of the energy is retained and carried away by the neutral molecule. From the similarity to heat and momentum exchange of a gas with a solid the ions are said to possess an "accommodation coefficient" less than unity. Compton proposed that the existence of an accommodation coefficient, whereby neutralized ions leave the cathode with considerable momentum, could account for the reaction upon the cathode of a vacuum arc.

In effect, by this theory a more dense stream of low velocity particles is substituted for the less numerous high velocity particles of Tanberg and Kobel. Since the mass of positive ions striking the cathode per second might be much larger than the mass of the net vaporization from the cathode, the observed reac-

tion could be accounted for if the neutralized ions left the cathode with a small part of the energy acquired from the cathode fall space. Compton calculated that a retention of only 2 per cent to 5 per cent of the incident energy—less than 0.5 equivalent volt—would be necessary for the copper and mercury arcs, if half the current were carried by positive ions; if a smaller part of the current were carried by positive ions, then the accommodation coefficient would have to be still smaller. While small values do exist for light atoms, the accommodation coefficient for heavy ions, such as copper or mercury, has not yet been measured.

Even though the mechanism suggested by Compton may possibly picture correctly the way in which the reaction is imparted to the cathode, it has been pointed out[4,9] that the necessity of a high velocity vapor stream leaving the cathode region remains. The force on the cathode must be balanced by the momentum of the particles escaping from the cathode region; since a low pressure existed during the experiments, the flow of momentum can be carried only by the vapor corresponding to the net loss in weight of the cathode. Consequently, the velocity calculated for this vapor must be correct. The suggestion offered would not account for the high speed vapor striking the vane before the cathode. If the Compton theory is valid, then an equal difficulty remains in devising a way by which the many molecules with low velocity may transfer their momentum to a few molecules with high velocity.

Risch and Lüdi's Theory

Risch and Lüdi[10] have recently proposed a theory, somewhat like Compton's theory, but avoiding the difficulties there encountered. An electrical mechanism is provided for the attainment of high velocity by the particles leaving the cathode region. Positive ions incident upon the cathode possess both kinetic energy, acquired from the field, and potential energy, in virtue of their ionization. Risch and Lüdi propose an accommodation coefficient for the potential energy; that is, positive ions are neutralized at the cathode but some of the energy set free in this act is presumed to be converted into kinetic energy of the neutral particle. Most of the atoms evaporated from the cathode are ionized and drawn back before escaping completely; after neutralization, they leave at a high velocity. Upon this assumption, the ion current is equal to the net material loss from the cathode. In order to supply thermal losses from the cathode and to provide for the large kinetic energy of the escaping vapor, it is necessary to suppose that the positive ions are multiply charged—that they have been ionized 6 or 7 times. This Risch and Lüdi believe possible, because such a dense stream of electrons is coming from the cathode that a copper atom would be struck many times while it remained in the cathode region, and the time intervals between collisions would be too short for the atom to radiate away the energy received from the electrons. Thus ionization would proceed by cumulative action until an ion would possess several hundred volts potential energy. Risch and Lüdi's calculations for the copper arc run briefly thus: If 86 per cent of the current is carried by electrons (see below) a current density of 14,000 amp/cm^2 corresponds to 7.5×10^{22} electrons/cm^2-sec. If the cross section of a copper atom is 10^{-15} cm^2, each atom will be struck 7.5×10^7 times per sec, and the mean time between 2 impacts is about 10^{-8} sec—too brief for radiation to occur. The energy lost from the cathode by conduction is taken as 3 watts/amp, and by electron cooling as 7 watts/amp. The loss of 1.5×10^{-5} g/amp-sec of copper is equal to 1.4×10^{17} molecules/amp-sec, so if this is taken equal to the ion current, the elementary charges that must be conveyed per ion are:

$$\frac{1}{1.4 \times 10^{17} \times 1.59 \times 10^{-19}} = 44$$

If the ions bear 6 charges, then 38 electrons (or 86 per cent of the current) must be freed for each positive ion. If the energy of the departing neutralized ion is 140 equivalent volts, then the total energy loss per ion is $(7 \times 38) + (3 \times 44) + 140 = 540$ volts. Of this, kinetic energy can provide $6 \times 15 = 90$ volts (6-fold charge times assumed 15 volts cathode fall), leaving 450 volts to be supplied as potential energy—corresponding to 6 or 7 times ionized. Since an electron would have only 15 volts energy at the cathode fall boundary, at least 30 electron impacts per ion formed are necessary. This would involve only 30×10^{-8} sec, too short a time for the ion to move far.

The cross section for excitation of an atom is considerably less than the kinetic theory cross section used above, so the time between exciting collisions might possibly be longer than the mean time of existence of an excited atom without radiation. Though this and other minor objections might be raised, at present there seems to be no definite proof of the impossibility of the explanation of Risch and Lüdi. Indeed, in the arc where the energy density is so much greater than in other forms of discharges, it would not be surprising to find higher states of ionization than exist in other discharges. The idea of multiple ions is entirely new to the theory of the arc cathode, and certainly must be taken into consideration as a possibility in the formulation of a theory of the cathode. Any complete theory of the arc must embody an explanation of the origin of the high velocity vapor stream.

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Electrochemistry and Electrometallurgy—1932-33

In the field of electrochemistry and electrometallurgy several developments have been brought forth during the past year, which are deemed worthy of record. These are outlined briefly in this report by the Institute's committee on electrochemistry and electrometallurgy.

WHILE the engineering and research activities of many organizations have been curtailed considerably during the past year, several developments have been brought forward which are worthy of record. Those which have been brought to the attention of committee on electrochemistry and electrometallurgy are mentioned briefly here.

High Temperature Steel Treating Furnaces

Development work is being carried out actively to meet the increasing demand for industrial furnaces in steel treating work where temperatures of 2,000 to 2,500 deg F are required. Inductive methods of heating in some cases work out very satisfactorily; in other cases, resistance heating, either by direct conduction or by radiation, will meet the requirements better. There is a definite field for the electric furnace in this temperature zone, and progress is being made in filling it satisfactorily.

Electric Furnace Irons

The term "electric steel" has denoted for a long time superior steels made in the electric furnace. The comparatively new term "electric furnace iron" denotes superior grades of cast irons which are the products of the electric furnace. The main feature in the production of these irons is the heat treatment of the molten metal at temperatures beyond the range of the cupola. These new irons are marked by high tensile strength and uniformity. The growing demand for these products of the electric furnace is enlarging materially the field of electric heat for producing molten metal.

Lithium

The production of lithium now has been established on a commercial basis in this country. This metal is being used as a hardener for aluminum and lead alloys. It is being used also as a superscavanger in ferrous and non-ferrous metal production, and in the degasification of copper. The latter application is of special importance to electrical engineers in connection with the manufacture of high conductivity copper.

Process Regulation

Manual control of hydrogen ion concentration in flotation, electrolytic reduction, and refining plants is expensive, slow, and inaccurate. Two schemes have been worked out for the automatic regulation or control of hydrogen ion concentration which employ photoelectric tubes in such a manner as to avoid errors caused by line voltage variation, temperature variation, or changes in tube characteristics with age. Both of these schemes supply an adjustable inoperative time during which a correction is allowed to take effect before the regulator is permitted to attempt a second correction. This equipment should find application not only in the control of hydrogen ion concentration but in control of color or opacity of a solution which is affected by a single varying chemical.

Accurate control of high temperature has been made possible by the development of a high temperature indicator and regulator employing the electrical conducting characteristics of certain refractory materials at high temperatures. The refractory material receives radiant energy direct from the material whose temperature is to be regulated, and thus the resistance of the refractory material is proportional to the temperature. The material is placed in a bridge circuit which is balanced for the desired temperature or resistance of the refractory material. Any deviation from this temperature, of course, unbalances the bridge circuit and the unbalanced current is amplified and used to control the power input to the furnace in order to bring the temperature back to the desired value.

Operating power costs have been decreased by the application of power regulators to improve the load factor of a plant. In electrolytic plants it has proved practicable to raise the load factor to 100 per cent thus obtaining a minimum power cost for producing a given amount of product, since the total kilowatthours are regulated to equal the past average kilowatthours.

Electrolytic cell efficiencies have been increased by the application of constant current regulators, maintaining the cell circuit at the optimum value of current considering both efficiency and production requirements.

Electrical Precipitation

In addition to those fields of application where electrical precipitation processes have been used in the past, these processes have recently been adapted to problems of gas cleaning in iron blast furnace and paper mill operations.

Progress has been made in the development of hot cathode vacuum tubes for high voltage rectification

Excerpts from the annual report of the A.I.E.E. committee on electrochemistry and electrometallurgy for 1932–33. *Not published in pamphlet form.*

Committee on electrochemistry and electrometallurgy, 1932-33: W. C. Kalb, *chairman;* Herbert Speight, *vice-chairman;* J. C. Hale, *secretary;* Lawrence Addicks, P. H. Brace, L. W. Chubb, F. G. Clark, S. K. Colby, G. W. Elmen, W. E. Holland, F. A. Lidbury, R. G. Mansfield, K. L. Scott, N. R. Stansel, Magnus Unger, H. B. Vidal, G. W. Vinal, J. B. Whitehead, J. L. Woodbridge, and C. D. Woodward.

for electrical precipitation. Voltages up to 100 kv have been successfully rectified, though this is in excess of the normal requirements for precipitation, which does not exceed 75 kv. The field for high voltage rectification is not confined to electrical precipitation, for X ray applications, cable testing, and electrostatic separation schemes all require such a supply.

Electrolytic Hydrogen

During 1932 a 6,500-kw 650-volt mercury arc rectifier was put into service for producing hydrogen by electrolysis. This rectifier consists of 2 3,250-kw tanks operating from one transformer. A primary regulating transformer provides a range in the d-c voltage from 600 to 670 volts. This equipment is used in a new atmospheric nitrogen fertilizer plant, and has been in successful operation for about a year.

Electricity in Chemical Processes

Application of electricity to chemical processes was reviewed by Dr. Colin G. Fink in an address which proved to be the salient feature of the session sponsored by this committee at the 1933 winter convention. In this address Doctor Fink presented much valuable data relative to the use of electrical power in chemical and metallurgical industries. The address having been published in the March, 1933, issue of Electrical Engineering (p. 151–4) no repetition of the data is included in this report.

Pulling-Into-Step Equations Solved

By means of the "differential analyzer," the equations describing the pulling-into-step transients of a synchronous motor can be solved readily and accurately. The results of such solutions give a rather complete analysis of pulling-into-step phenomena, and thus make possible the determination of the performance of practically any synchronous motor. Practical application of the study is illustrated by a numerical example.

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A MECHANICAL calculating machine[1] named the "differential analyzer," developed at the Massachusetts Institute of Technology under the direction of Dr. Vannevar Bush, has made it possible to solve rapidly and accurately the non-linear differential equations that represent the constraints upon the motions of synchronous motors during transient conditions.

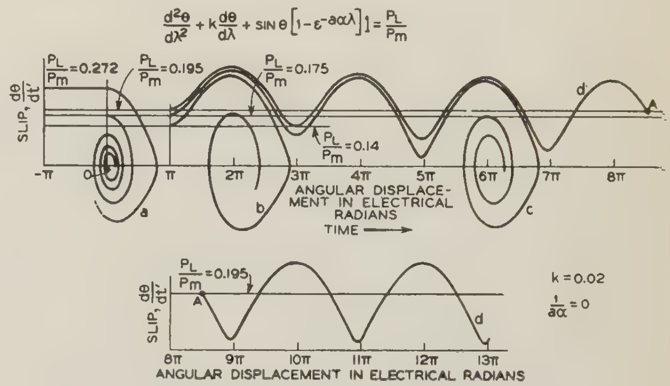


Fig. 1. Actual differential analyzer slip-angle solutions of the equation of motion of a round-rotor synchronous motor during pulling-into-step transients

Three previous investigations[3,4,5] of synchronous-motor phenomena have been made with a preliminary experimental calculating machine[2] which was called the "product integraph." The difficulties of manipulation and the inherent errors of that machine limited the extent and accuracy of the solutions. Now, with the new and accurate differential analyzer, all of the previous work on the pulling-into-step problem has been repeated and greatly extended. The solutions have been extended to include the "best" switching condition and the condition for "ultimate" synchronization, as well as the "worst" switching condition, which was the goal of the previous investigations. Complete graphs of the regions of stability and non-synchronous operation have been determined for all practical cases. Also the effect of the field time constant has been included as another factor.

Charts compiled from the results of many solutions make it possible to calculate quantitatively the ad-

Based upon "Synchronous-Motor Pulling-Into-Step Phenomena" (No. 33-26) presented at the winter convention of the A.I.E.E., New York, N. Y., Jan. 23–27, 1933.

1. For all numbered references, see bibliography at end of article.

vantages of angularly controlled field switching. These advantages are summarized as follows:

1. From 0 to 45 per cent more load can be synchronized with switching controlled to approximately the most favorable angle, compared with that for ultimate synchronization. The gain depends upon the relative damping factor and the relative time constant of the motor as shown in Fig. 7. The largest gain is realized with high resistance amortisseur windings, large inertia loads, and small field time constants.

2. With angularly controlled field switching, a given motor and load can be pulled into step from a larger slip. The practical meaning of this is that the amortisseur windings do not need to raise the speed to as high a value. Therefore, higher resistance amortisseur windings may be used, resulting in better starting characteristics.

3. When the field is switched at the most favorable angle, the slip during the transient never exceeds its initial steady-state value. For the most unfavorable switching condition the slip during the transient is from 60 to 200 per cent larger than its initial steady-state induction-motor value, depending upon the relative damping factor as shown in Fig. 8.

4. Favorable switching minimizes the mechanical and electrical surges that accompany the pulling-into-step transient when the field of a motor is applied at unfavorable angles.

Thus controlled field switching offers advantages for synchronous-motor applications where the starting conditions are difficult, the inertia is large, or the load at the time of pull-in is large.

Cylindrical Rotor

For any round-rotor synchronous-induction motor brought up to speed as an induction motor, there are 6 major factors that determine whether the motor will pull into step. These are:

1. Load on the motor during the synchronizing period.
2. Maximum synchronizing torque due to the synchronous-motor effect.
3. Field time constant.
4. Induction torque-slip characteristic (assumed linear).
5. Inertia of the motor and connected load.
6. Switching angle θ_0 that exists when the exciter is connected; this is the electrical angle between the axis of the actual field pole and an imaginary field pole that would generate the terminal voltage on open circuit.

When these 6 factors are known, the data given in this article makes it possible to determine the maximum shaft load with which the motor will synchronize and the most favorable switching angle θ_0. As it is desirable to have the motor pull into step on the first swing through the steady state operating angle, the criterion established for pulling into step is that the final steady state operating angle shall be attained without the motor swinging more than once through a complete generator cycle after the field is applied.

The equation of the pulling into step of a synchronous induction motor generally is accepted to be of the form

$$P_i \frac{d^2\theta}{dt^2} + P_d \frac{d\theta}{dt} + P_m \sin\theta\,(1 - \epsilon^{-\alpha t})\,\mathbf{1} = P_L \tag{1}$$

where

P_i = coefficient which when multiplied by the acceleration in electrical degrees per second per second gives the component of power accelerating the inertia (at synchronous speed)

P_d = coefficient which when multiplied by the slip in electrical degrees per second gives the component of power due to the induction motor effect (assumed constant in the solutions)

P_m = maximum power due to the synchronizing action of the field current

P_L = shaft load at synchronous speed (considered constant in the solutions)

$\frac{d^2\theta}{dt^2}$ = acceleration in electrical degrees per second per second

$\frac{d\theta}{dt}$ = slip in electrical degrees per second

θ = the angle in electrical degrees which exists between the axis of the actual field pole and an imaginary field pole that would generate the terminal voltage on open circuit

θ_0 = the value of θ when the exciter is connected

$1 - \epsilon^{-\alpha t}$ = term taking into account the effect of the field time constant

$\mathbf{1}$ = Heaviside's unit function, which is zero before and unity after time equals zero

In deriving the equation it is assumed that the armature currents and potentials are sinusoidal, that the applied armature and field potentials are constant, and that the stator resistance and the effect of the rotor leakage inductance are negligibly small.

To facilitate solution by the differential analyzer, the equation can be reduced to a more convenient form by dividing through by P_m and replacing t by a new dimensionless variable λ; this gives the equation

$$\frac{d^2\theta}{d\lambda^2} + k\frac{d\theta}{d\lambda} + \sin\theta\,(1 - \epsilon^{-\alpha a\lambda})\,\mathbf{1} = \frac{P_L}{P_M} \tag{2}$$

where

$$k = \frac{P_d}{\sqrt{P_i P_m}} \text{ and } \lambda = \frac{t}{a}$$

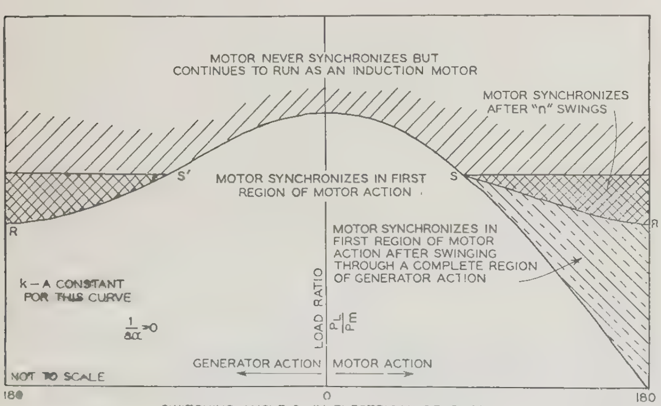


Fig. 2. Diagrammatic chart classifying switching angles and corresponding load ratios

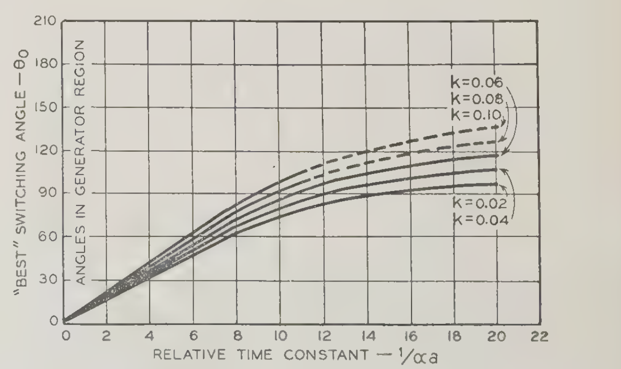


Fig. 3. Best switching angles for a round-rotor synchronous motor; note that all the angles refer to generator region

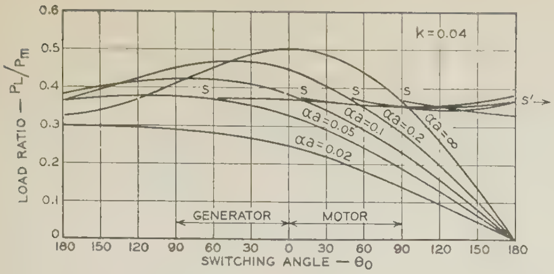


Fig. 4 (left). Effect of time constant of field circuit on the performance of a round-rotor synchronous motor

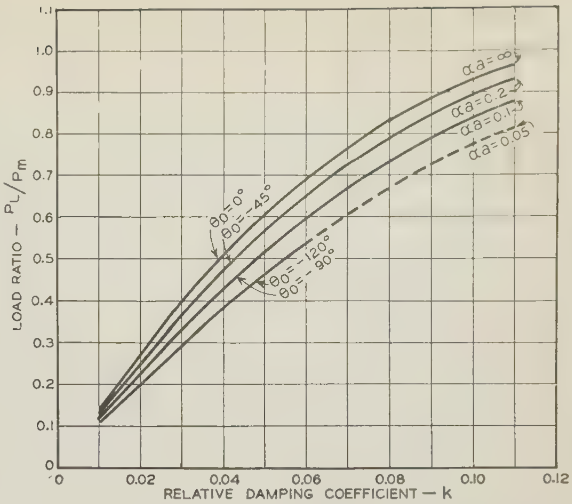


Fig. 5. Curves for a round-rotor synchronous motor showing maximum load ratio that may be pulled into step vs. relative damping coefficient for best angle switching and for constant values of relative time constant

The term a is selected so that the coefficient of the acceleration term and the coefficient of the sine term shall be unity. For this condition

$$a = \sqrt{\frac{P_j}{P_m}}$$

The factor k, called the relative damping coefficient, is a numeric containing the dimensions of angle, and is proportional to the square root of the magnitude of the unit used for measuring angle. In the solutions that follow, angle is measured in electrical degrees; if electrical radians be used, k would be multiplied by $\sqrt{180/\pi}$. This factor k combines the terms P_d, P_j, and P_m, which depend upon the motor under consideration, into one factor. Thus all machines having any given value of k respond with similar electromagnetic transients, in terms of λ, when similar disturbances are imposed upon them; this is true regardless of the size of the machine.

Factors influencing the pulling into step of the motor now have been reduced to 4 as follows:

k = the relative damping coefficient

P_L/P_m = the load ratio

θ_0 = the value of θ when the exciter is connected

$\frac{1}{\alpha a}$ = relative time constant

To be able to predict what will happen in any particular machine, it is necessary to have a range of solutions covering all values of these coefficients found in practical machines. Accordingly, several solutions were made, each for a different value of k, θ_0, and $1/\alpha a$. Typical solutions of this type are shown in Fig. 1.

For the chosen value of k, initial switching angle and load ratio, the curves show how the angle θ and the slip subsequently varied. Curves b, c, and d, Fig. 1, are for $k = 0.02$ and $\theta_0 = 180$ deg. For a value of $P_L/P_M = 0.14$ (curve b) the machine synchronized on the first swing, conforming with the criterion. For a value of $P_L/P_M = 0.175$ (curve c) the machine synchronized on the third swing, hence did not conform to the criterion. From a family of curves such as these the chart in Fig. 2 was constructed.

After making several solutions of the type shown in Fig. 1, it became apparent that a critical solution is one giving a final steady-state operating position on the unstable portion of the power-angle curve such that the synchronous torque then developed is the same as it would be if the machine were operating in a stable position. In other words, the motor reaches a condition of zero slip and zero acceleration in the unstable region of the power-angle curve, with the load torque exactly balanced by the synchronous torque. When the relative field time constant is zero, this knowledge permits the use of a valuable characteristic of the differential analyzer, namely, that it can be operated either forward or backward. If the final conditions for a critical solution be known, the machine may be set to conform to these conditions and operated so that time proceeds in a reverse direction. It will then solve for the initial conditons necessary to give the known final result.

In Fig. 2 the various possible types of solutions and the switching conditions that give rise to them are classified into regions. A point on this chart has as its coördinates the load ratio P_L/P_m and the switching angle θ_0, the entire chart being drawn for a particular value of k and of $1/\alpha a$. Points that lie in the unshaded portion of the chart show the load ratios and switching angles for which the motor will synchronize without swinging beyond the first region of motor action. For points lying in the region shown by dotted cross-hatching the motor will synchronize in the next region of motor action after passing through a complete region of generator action. Points within these 2 regions are the only ones for which the motor will synchronize and satisfy the criterion. For points lying in the region shown by lattice cross-hatching the motor will synchronize eventually after passing through several motor and generator cycles. It was proved definitely that points lying within these 3 regions are the only ones having coördinates of load ratio and switching angle for which a motor with the given value of k and $1/\alpha a$ ever will synchronize.

The load ratio corresponding to points S and S' becomes significant since it is the maximum that can be synchronized eventually when the switching angle is uncontrolled. This load ratio may be called "the ultimate load ratio."

With data obtained from families of curves of the type shown in Figs. 1 and 2, Figs. 3 to 7 were pre-

pared. The captions are self-explanatory; hence, it is not necessary to discuss the curves here.

Salient Pole Motor

The theory of the pulling-into-step phenomena for a salient pole synchronous motor has been given in the results of a previous study[5] made on the product integraph. Some of this work has been repeated and extended with the new differential analyzer.

The study of the salient pole motor involves the use of a more comprehensive equation than does the motor with a cylindrical motor. Only the graphical results of the present study are given here. Methods of obtaining the results are identical with those used for the round-rotor motor except that the initial slip is not constant. Variation of the initial slip is due to the torques caused by the reluctance effect of the salient poles and the incompleteness of the amortisseur windings. Both of these torques are functions of angular displacement.

Figure 9 gives 2 curves (marked $P_L/P_m = 0.3$) showing the range of load ratio which will just allow pulling into step, as a function of the relative damping coefficient for a salient pole machine having a reluctance torque equal to 30 per cent of that torque which is a sine function of the angular displacement. In these curves the damping is considered to be equivalent to that of a round-rotor motor; that is, the induction motor torque does not vary with the angular displacement. The lag of the building up of the field has been neglected for this aspect of the problem, since the conclusions of the extensive study of the effect of the field transient on the round-rotor machine undoubtedly apply to the salient pole machine.

Other curves (marked $b = 0$) on Fig. 9 show the largest load ratios that are permissible as a function of the relative damping factor for a cylindrical-rotor motor with a damping torque that varies as a cosine squared function of the angle. The effect of the field time constant was neglected in these curves also for the same reason as in the salient pole curves.

The curves of Fig. 9 show that the salient poles and incomplete amortisseur windings do not greatly influence the ratio between the critical load ratio and the relative damping coefficient. The explanations for this are:

1. The excursion of the angle covers such a large range of values that only the average coefficients of the differential equation are of importance.

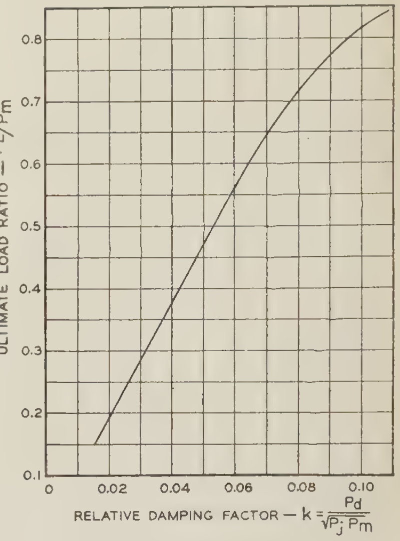
2. Torque variations before the field circuit is energized cause the instantaneous initial slip to vary in such a manner that the initial slip is a maximum at what otherwise would be the most favorable switching angle. Thus the expected gain from saliency largely is neutralized.

Maximum slip during the transient is plotted as a function of the relative damping factor in Fig. 8. The salient pole motor has a larger variation of maximum slip than does the round-rotor machine.

Practical Application of Differential Analyzer Solutions

Previously mentioned papers[4,5] demonstrated the manner in which the solutions were applied to determine whether or not a synchronous motor would synchronize for the *worst switching condition.* A mathematical inequality was determined from the slope of the curve that separated the region of unstable solutions from the stable ones, and thus made it possible to obtain useful relationships such as expression 5 of

Fig. 6. Curve for a round - rotor synchronous motor showing "ultimate" load ratio for any value of switching angle θ_0 and any field time constant



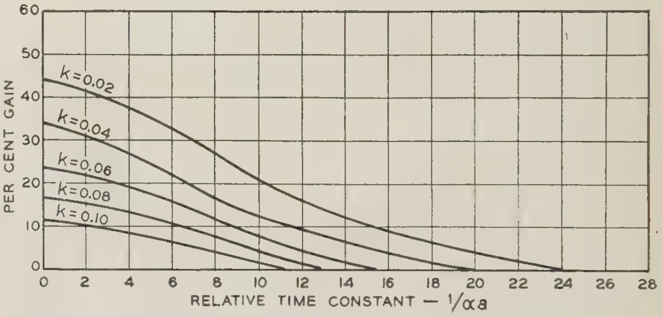


Fig. 7. Curves for a round-rotor synchronous motor showing the additional load that may be pulled into step when field switching occurs at the "best" angle, as a ratio to that which may be pulled into step "ultimately"

reference 5, or expression 7 or 8 of reference 4. Data from differential analyzer solutions show the error that results from taking such a linear relationship. Figure 9 shows the actual curve for the most unfavorable switching condition. If the load ratio is between the limits 0.1 and 0.8 it is justifiable to use a straight line relationship, which is certainly within the precision of the determination of the coefficients and constants of a synchronous motor.

Curves included in this article make it possible to calculate quantitatively the additional load that may be synchronized if the field switch is closed at the *most favorable switching angle.* As may be seen from Fig. 4, this angle may be varied about 10 deg from the optimum value without seriously influencing the maximum load ratio. This should permit considerable simplification of the field switching device.

An important factor which is always present to some degree in all motors, but which has been

neglected in this study, is the amount of non-linearity of the slip-torque curve of the motor. The results given apply only to motors that have linear slip-torque curves for the entire transient excursion of slip, and that have the same slip-torque curve before as well as after the field circuit is energized. Therefore, engineering judgment needs to be exercised in applying the results to practical motors. If the slip-torque relationship is non-linear, the chart showing the per cent gain will be pessimistic; that is, angularly controlled field switching will yield a larger gain than is predicted by the results of this study. The reason for this is that the range of slip for the best switching condition is different from that for the ultimate or the worst case. As can be seen from the characteristic solutions shown in the left-hand side in Fig. 1, the slip for the best switching condition never exceeds its initial value, while the slip for the worst condition increases greatly because of the swing through the generator region. Since the deviation from the linear part of the slip-torque curve increases as the slip increases, the results given for switching under the most unfavorable angle will be affected more than the results for switching at the most favorable angle. Thus motors having values of k and $1/\alpha a$ for which the charts show no gain, actually may realize a gain because of the non-linear aspects of the slip-torque curve.

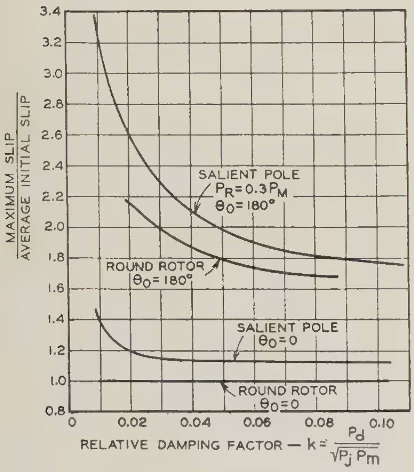
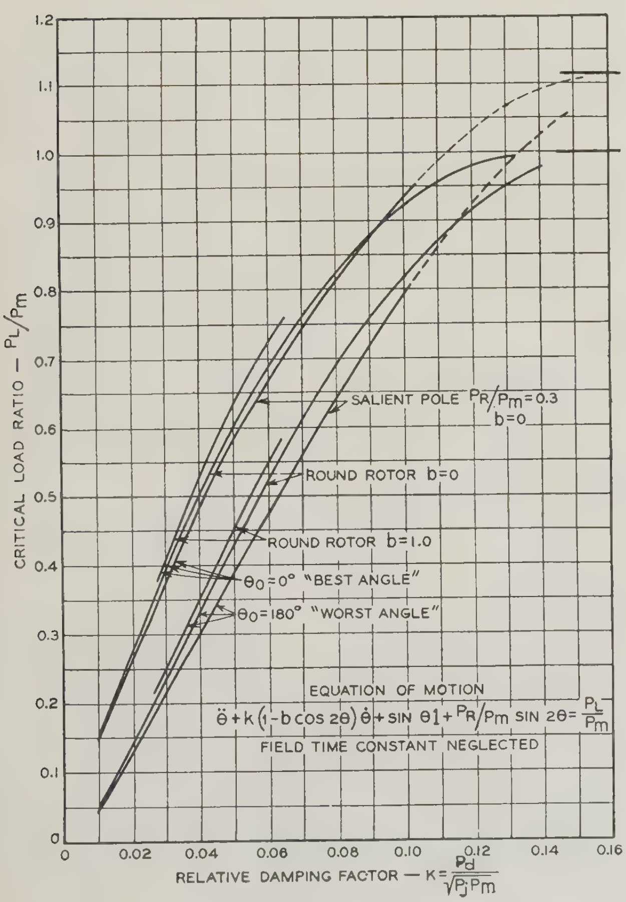


Fig. 8. Transient slip variations

Fig. 9 (below). Critical load ratio of synchronous motors



In what follows, the data necessary for determining the synchronizing characteristics of a synchronous motor are listed, and a complete sample calculation is given. The units used for numerical values on the curves correspond to electrical degrees and therefore the angle must be expressed in electrical degrees. A convenient unit for torque is the synchronous kilowatt since the speed does not vary far from synchronous, and since the machine characteristics usually are expressed in kilowatt units.

Necessary Data

P_j inertia coefficient in kilowatts per electrical degree per second per second

$$P_j = 18.6\,\frac{(WR^2)f}{p^2} \times 10^{-6} \text{ kw per elec deg per sec}^2 \qquad (3)$$

where
WR^2 is the moment of inertia in pound-feet^2
f is the frequency in cycles per second
p is the number of poles
P_d damping coefficient in kilowatts per electrical degree per second

$$P_d = \frac{P_L}{360fs} \text{ kw per elec deg per sec}^2 \qquad (4)$$

where
P_L and s are taken from the near-synchronous straight-line portion of the slip-torque curve
P_L is the load torque in synchronous kilowatts
s is the corresponding per-unit slip
P_m synchronizing torque in kilowatts for θ = 90 deg
P_L load on the motor in kilowatts
n synchronous speed in revolutions per minute
$\dfrac{1}{\alpha}$ field time constant with armature short circuited

Example: Sintering Fan Drive

The motor was an 8-pole machine having the following rating:
60 kva, 900 rpm, 440 volts, 75 hp, 1.0 power factor; total WR^2 = 4,000 pound-feet^2
P_j = 0.0697 kw per elec deg per sec^2
P_d = 0.170 kw per elec deg per sec
P_m = 117 kw
$1/\alpha$ = T_0 = 0.0955
P_L/P_m = 0.477

From the foregoing data the following constants may be calculated:

$$k = \text{relative damping coefficient} = \frac{P_d}{\sqrt{P_jP_m}} = 0.0594$$

$$a = \text{conversion factor} = \sqrt{\frac{P_j}{P_m}} = 0.0244$$

$$\frac{1}{\alpha a} = \text{relative time constant} = 3.91$$

The ultimate condition of just synchronizing is read from Fig. 6 entering with k = 0.0594 and reading P_L/P_m = 0.560. This shows that the motor is conservatively rated provided the slip-torque relationship is approximately linear. If in practise the load should be larger than normal, the curve of Fig. 7 shows that if the angle is controlled to the most favorable switching angle, then about 0.2 per-unit more load than the ultimate can be pulled into step satis-

factorily. The most favorable switching angle is 36 deg (generator) as read from Fig. 3.

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Modern Railway Signaling

Signal systems used on the Reading Railroad are described briefly in this article. Although the article is confined to details of signals and interlockings which are standard on that road, there are many features of interlocking and signal control that are common to most modern systems. The system described herein is the recent installation of 100-cycle a-c color light signaling.

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THE Philadelphia and Reading Railroad (now Reading Company) was one of the pioneer roads in the installation of automatic signaling and interlockings. The first form of signaling used was a manually operated 3-sided revolving tower, mounted on top of a raised signal cabin, and operated by a tower man in the cabin to protect train movements on curves. The first interlocking installation by the Reading Railroad on record is of a mechanical machine that was installed at Wayne Junction in 1880, followed by other similar installations at most of the important points. The development of improved types of interlockings is best illustrated by noting that the Wayne Junction plant has had 4 complete replacements of the interlocking machine since the original installation. The mechanical plant served from 1880 to 1901 when a low pressure air machine with pneumatically operated switches was installed. In 1911 the air machine was replaced with an all-electric interlocking machine, which in turn was replaced in 1929 by an improved type of all-electric machine. This last change was made in connection with the Reading's suburban electrification program.

Automatic signals were first installed on a portion of the Reading's main line in 1895. The signals were of the Hall disk type, which type of signal was standard until 1902 when the first 2 arm (home and distant) semaphore signals were installed. Following the advent of semaphore signaling the road's standard was changed to a single arm 3-position upper quadrant semaphore with marker light. This type of signal was in use until 1924 when the Reading, following experimental tests with various types of light signals, adopted the color light signal as standard.

As the most recent signaling installation on the Reading is located within its suburban electrified area, the following descriptions will be confined to this territory.

Power Supply and Distribution

The development of automatic train control and frequency selective track relays now commonly used in a-c electrified territories made necessary that signal frequencies be distinctive and free from the inductive effects of other a-c systems. To meet this condition a 100-cycle signal frequency is used, requiring converter sets at signal substations, where the supply frequency is converted to 100 cycles.

Electrical energy for the operation of automatic signals and interlockings is distributed at 4,400 volts from 10 signal substations located approximately 20 miles apart. Signal power is normally supplied from 5 of the stations; the remaining stations are located at the opposite end of each normal feed power section automatically controlled so as to take the signal load in the event of a failure of the normal supply.

Throughout all of the terminal territory the signal circuits are carried in a concrete encased fiber duct line using 2-conductor No. 2 or No. 4 lead-covered cable. In the outlying territory, signal lines are run in open wire on a wood pole line or on catenary structures.

All signal substations are non-attended except the Wayne Junction station where 4 signal lines radiating from this point are energized from a 100-cycle bus. The standby or reserve sets are started automatically and closed in on the line when machine voltage builds up to normal. Each station is controlled by a line relay which prevents it from closing on the line when the other station is supplying power. All frequency changer sets are provided with thermal protection on the motor and the generator has a full

Based upon "Modern Signaling on the Reading Railroad" (No. 33-21) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933. Essentially full text of the paper is presented herewith, excepting only the description of automatic train control which is combined with other information on this subject in another article in this issue.

complement of undervoltage and overvoltage relays checking performance; outgoing 100-cycle feed is protected with a manual reset overload relay.

At Wayne Junction where there is parallel operation of 2 120-kva frequency changer sets feeding a 100-cycle bus, the use of induction type motors necessitates special provision for synchronizing. During part of the day it is possible to carry the load with one machine, but at peak load periods the second machine must be operated. At the time this second machine is closed in on the bus the first machine is operating at nearly full load, its frequency being synchronous less the slip frequency. To compensate for the difference between the frequency of the loaded and the incoming machines, an arrangement is used whereby a phantom load is placed on the incoming machine. This provides control of the incoming machine, regulating its speed to approximately that of the operating machine. The control circuits are arranged to drop the phantom load automatically when the second machine is connected to the bus. A current compensating circuit operating on the machine voltage regulators insures an equal division of the wattless current. The division of power current is, of course, determined by the speed of the respective machines. The slip curves of these machines coincide very closely and the power current of the 2 machines is equal under all load conditions.

The exacting voltage regulation required on signal lines makes it prohibitive to have an instantaneous drop in voltage when dropping one machine from the bus. To overcome this a circuit arrangement eliminates the current compensation and over-excites the machine that will remain on the bus. With this arrangement there is no noticeable drop in signal voltage in placing a machine on or off the bus.

Transformers are 4,400/110 volt, oil cooled, of capacities varying from 0.25 to 15 kva. No grounding is permitted of either the primary or secondary transmission systems, thereby isolating the signal circuit from the effects of other grounded systems. At transformer locations in open wire territory both lines of the 4,400-volt circuit are protected by lightning arresters. A separate earth connection is run to the transformer shell.

Lighting for all the smaller stations in the electrified territory is taken off the 4,400-volt 100-cycle signal line. Where a station lighting and signal connection is required at the same location a double secondary transformer is used, thus permitting use of a grounded secondary lighting circuit without introducing grounds in the signal circuit.

Signals

The modern signals are all of the long range color light type arranged with 2 or 3 light units; light signal cases are ventilated, and the entire lamp unit and case is assembled so that the lamp filament is in the exact focal point of the lens system. Accurate alignment is procured in the field by the use of a portable sighting telescope. On tangent track the signals are focused for a long range indication. On curves the signal is focused to the far point of the curve where the indication should first be picked up by the engineman. Continuous indication for approach on curves is provided by using a 10-deg or 20-deg deflecting prism or spread lens in which light rays are deflected in a horizontal plane toward the arc of the curve. (See Fig. 1.)

The lamp unit consists of a doublet lens with outer lens clear and inner lens colored. The lamp receptacle is supported in fixed relationship to the lenses. Thus, lamps are interchangeable. In addition to the doublet lens each unit has a small deflecting lens held in position by a spiral spring, immediately back of the center of the front or clear lens. This lens is commonly called a close-up prism and provides an intense color display in the center of the signal front lens, when the train is stopped immediately under or opposite a signal. Lamps used are of the double filament type rated at 10 volts, 18 watts. These are lighted at $9^1/_2$ volts to insure a long burning life.

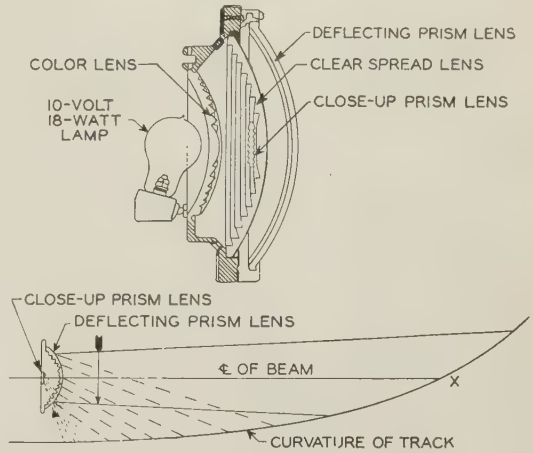


Fig. 1. Lens arrangement and method of focusing of a light signal

Solid lines represent beam spread of clear lens
Broken lines represent beam spread of deflecting lens
Dotted lines represent concentrated light beam for close-up view

Signals are located on masts to the right of, or on catenary structures, immediately over the right rail of the track governed. Where signals are mounted on catenary structures they are located 21 ft above the top of the rail. Ground masts are located to the right of the track governed, with near side of mast 10 ft from the center line of track. Signal units of interlocking signals are arranged as follows:

1. Two-unit signal. Center of red lens of bottom or slow speed unit 10 ft above top of the rail with 12 ft spacing to center of red lens in top unit.
2. Three-unit signal. Center of red lens of bottom or slow speed unit 10 ft above top of rail with 7 ft spacing to middle and 5 ft middle to top unit.
3. Automatic signal. Center of red lens of marker light or third block indication unit 10 ft above top of rail and 7 ft between red lens of marker and automatic signal unit.

Automatic Signals

In general the automatic signaling is of the 3-indication 2-block type; however, at approaches to interlockings where a restricted route signal may be

displayed or where the spacing between automatics does not provide sufficient braking distance 4-indication 3-block signaling is installed.

Existing installations made prior to electrification had both polarized line or clearing and track relays. In electrified territory where track circuits are limited to the use of 2-position frequency track relays, recent installations have been made with neutral line control. This form of control is adaptable for future extension of cab signal territory.

Line control circuits are normally energized, but the signals are lighted only during the time a train is in the approach block to the signal and until the block beyond the signal is cleared. Where more than one track is signaled in the same direction, signals for both tracks at the same location are lighted by the approach of a train on any one track.

Automatic signal control provides that a stop indication be displayed when:

1. Train, engine, or car is in the block immediately in advance of the signal.
2. Any switch or derail in block is reversed or switch points not fully closed in their normal position. A switch point tolerance of less than 1/4 in. is permitted.
3. A rail is broken, interrupting track circuit.
4. Cars extend beyond the fouling point on sidings.

Interlockings

Electropneumatic interlocking plants are installed throughout most of the terminal territory where frequency and speed of operation are important factors. However, power interlockings are not all of the electropneumatic type. There are a number of all-electric plants in service. Interlocking circuits provide a standard arrangement of approach, sectional route, and detector locking.

Approach locking is an arrangement of electrical control which permits changing signal from the proceed to the stop indication, but acts to prevent any change of route in advance of an approaching train. A release is provided in the approach locking circuit through the medium of a clockwork time release set for 2-min operation. Circuits are arranged so that time delay must follow the change of signal from proceed to the stop indication.

Sectional route locking provides for the electrical control of detector locks on switch levers throughout an entire interlocking route. When the interlocking signal is cleared for an approaching train, all switch and opposing signal levers are locked mechanically in the machine. The electrical route locking becomes effective when a train passes the signal governing movement through the interlocking.

Detector locking is the electrical control to the normal and reverse locks of switch levers which acts to prevent movement of switches located within the limits of a track circuit in which a train is located or within a section of route locking in advance of the train.

Track Circuits

The operation of approach, route, and detector locking in interlockings and the control of both interlocked and automatic signals is all based upon the signal track circuit. (See Fig. 2.) Track circuit limits are defined by insulated joints placed in the track rails. At one end of the circuit current is fed to both rails of the track from a 300-voltampere transformer with variable secondary voltages. At the other end a relay is energized from rail connections. When a train enters the circuit, track current passes through the wheels of the rolling equipment short-circuiting the normal current path and deenergizing the relay. The deënergizing of the track relay opens the front and closes the back contacts over which signal circuits are controlled. All of the track relays used in electrified territory are of the centrifugal frequency type which are selective between the 25-cycle propulsion current and the 100-cycle signal frequency. These track circuits are divided into single-rail and double-rail types. The double-rail circuit is used in automatic signal territory and requires a double coil impedance bond at each end of the circuit, to provide a return for the propulsion current. Single-rail track circuits are used in interlockings where the control of route and detector locking requires that each signal block be divided into a number of short track sections.

In the single-rail track circuit one of the rails is bonded straight through for propulsion current, the other rail being equipped with insulated track joints to define track circuit limits.

The use of single-rail circuits results in a saving in installation costs, as the only impedance bonds required are where the single-rail track circuits adjoin the double-rail type of the approach or receding track circuits to the interlocking. Double-rail track circuits vary in length. Where drainage and ballast conditions are favorable, a maximum length of 5,000 ft is permitted. The length of single-rail track circuits is limited to 1,200 ft so as to provide for broken rail protection.

Switch Operation

Power operated switches whether of the all-electric or electropneumatic type are controlled directly from rotary circuit controllers mechanically connected to levers of the interlocking machine. This control (usually 110-volts alternating current) actuates a polarized controller at the switch for all-electric movements or an arrangement of Z armature electropneumatic valves on the air plants. Actual switch operation thereby is controlled locally at the switch. In the electric movement the switch operating circuit is energized through contacts on a polarized controller from the 100-volt mains. In the same manner air is controlled locally at the switch from the main air line for the pneumatic movements. In each type of switch movement, motion is conveyed to switch points by means of a slide bar carried on antifriction rollers or guides to the switch operating rod through an open throat jaw or escapement crank.

The slide bar also provides a mechanical lock for switch points in both the normal and reverse positions. Locking dogs riveted to the slide bar are so arranged that they enter a narrow slot in switch lock

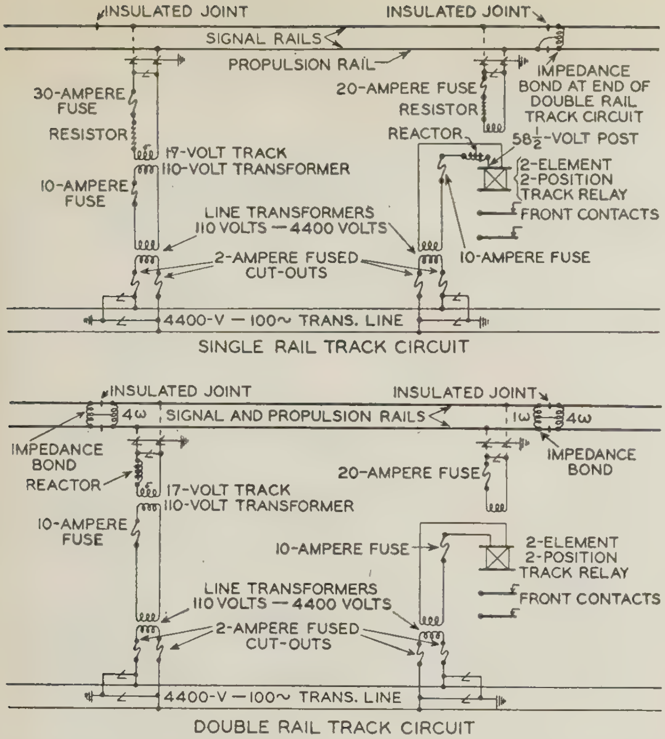


Fig. 2. Typical single and double rail track circuits

rod, which is directly connected to the switch points. Coincident with the locking of the switch, the power is automatically disconnected from the operating mechanism and switch points held in position by the mechanical lock. A switch point tolerance of not more than $^3/_{16}$ in. is permitted in the adjustment of this mechanical lock.

Having provided an operating control and a mechanical lock for switch movements, it is clear that a check should be made to insure that the switch has followed the movement of the control lever in the interlocking machine and that the switch is mechanically locked. This is accomplished by controlling the electromagnetic switch indication lock through a 3-position switch repeating relay. This lock acts to prevent placing the switch lever in full normal or reverse position until the switch has completed full movement of points and is mechanically locked. The indication circuit is a polarized control of a 3-position 2-element vane type relay, in which a controller mounted on and actuated by movement of the slide bar in the switch mechanism acts as a pole changer to the control element of the switch indication relay. This polarized control energizes the relay in a predetermined position when the switch is normal and to the opposite position when the switch is reversed. Circuits on the controller are so arranged that control wires to the switch repeating relay are shunted during the time that the switch is in transit. This same polarized switch repeating relay is used to control the clear position of signals routing through the plant.

Switch operation may be summarized as follows: First movement of slide bar unlocks the mechanical connection to the switch points and opens control of switch indication circuit, continued movement of slide bar actuates the switch points, the final movement of bar locks switch in the opposite position and closes indication circuit.

Light-out Protection

The lightning of signals is controlled over relay contacts with lighting circuit energized by a special 110/10-volt lighting transformer located in a relay housing adjacent to the signal. A special circuit was developed to check against a burnout of the lamp filament. The circuit arrangement provides a rectifier-controlled d-c relay in series with the lamp lighting and lamp filament circuit. Through this scheme of control it is possible to indicate the actual lighting or failure of a signal lamp by the medium of repeater lights in the tower.

Light-out circuits provide for the following features:

1. Automatic transfer of lighting circuit from an approach or clear indication to stop, in the event of a burnout when approach or clear is displayed; information is repeated to towerman who can then clear slow-speed signal for the route.
2. Checks that red lamp is lighted on normal route signal before proceed or approach indication can be displayed in restricted route signal. Under this circumstance the slow-speed signal may be cleared.
3. Checks that all red lamps are burning when signal lever is placed in normal or stop position, by controlling the approach locking circuits over lightout relays.

Model Board

Manipulation charts are provided in each interlocking tower indicating the proper sequence of switch and signal lever operation for the various routes. In addition to this chart, an illuminated model board is provided on which a complete track diagram indicates the location of switches, signals, track circuits within and the approach circuits to the interlocking. Track circuit limits on the model board are defined by colored sections of track including a miniature light in each section which is illuminated when that particular track section is unoccupied. Model board lights also repeat the stop and clear signal indications of the interlocked signals and in addition, the indication displayed at distant signals approaching the interlocking.

With this arrangement the towerman can follow the movement of each train from the time it enters the approach section until the interlocking proper is cleared, and it makes possible the control of 2 or more interlockings from a central point.

A summary of interlocking control in the sequence that it occurs follows:

1. The approach indicator and annunciator bell indicate the approach of a train.
2. Route is set by means of power operated switches with repeater lights and electric locks indicating track circuit conditions, and checking switch operation.
3. Signal is cleared, mechanically locking all switches and opposing signals in route, approach electric locking becomes effective, indication of interlocking home and the distant signal is repeated in the tower.
4. Train passes interlocked signal releasing approach locking; signal lever may now be returned to stop position, sectional route and detector locking becoming effective.
5. Release of route and detector locking in the rear of a passing train permitting a change in route for another move.

How Much Light?

An answer to the question of how much light should be used in the United States to give the proper level of illumination is given in this article. Based upon assumed values of illumination for various purposes, and upon an analysis of population, figures are derived which show the percentage of light used in terms of the desirable value.

THE PERCENTAGE saturation of the United States in artificial light is estimated approximately by the figures presented in this article. This saturation is given in terms of the estimated energy now used for lighting, divided by the amount of energy required to give certain desirable levels of illumination. Exactness is impossible, both because the ideal lighting levels for different kinds of human activity are still a matter of dispute among experts, and because accurate figures are not obtainable for the average daily hours of eye work of different kinds on the part of the average American.

In the preparation of these estimates there is assumed a statistical entity, the *average family*. The daily activities and surroundings of this average family then are divided, so far as artificial light is concerned, into 3 groups:

1. Those requiring what will be called work illumination, such as reading, writing, sewing, kitchen work, office work, skilled factory work, and salesrooms in stores.

2. Those requiring what will be called social illumination, such as eating, dressing, social activities at home, office reception rooms, unskilled factory work, and places of public assembly such as hotel lobbies.

3. Those requiring what will be called utility illumination, such as halls and passages in homes, storage rooms and warehouses, factory yards and passages, and city streets.

The criterions for these 3 classifications are roughly as follows: For work illumination the criterion is an amount of light sufficient for rapid and accurate reading of ordinary newspaper type (7 point) at the usual reading distance of approximately 18 in. and without notable eye strain on the normal eye. For social illumination the criterion is what might be called the conversational lighting level; that is, the amount of light necessary to recognize without difficulty the facial expression of another person at a distance of 10 to 15 ft. This is approximately equivalent to the light necessary to recognize the faces and spots of playing cards with ease at the average distance of a table top from the player's eye. For utility illumination the criterion is the lighting level necessary for recognition of the identity of a reasonably familiar person at a distance of 15 to 20 ft.

Lighting levels necessary to produce these 3 degrees of effective illumination are then computed, taking into account 4 different grades of lighting, ranging from the lowest levels believed permissible for good practise up to the highest which conceivably might be advisable. These 4 grades of lighting may be specified as follows:

1. Minimum "good practise" according to present lighting standards and ideas.

Table I—Summary of Assumed Lighting Levels for Good Seeing

	Work Illumination	Social Illumination	Utility Illumination
Minimum "good practise" at present	15 ft-c	5 ft-c	3 ft-c
Minimum recommended levels	30 ft-c	10 ft-c	5 ft-c
Probable levels of greatest economic advantage	50 ft-c	15 ft-c	5 ft-c
Possible desirable levels from eye considerations only	300 ft-c	50 ft-c	30 ft-c

2. The minimum level recommended by this group of inquirers, under existing economic conditions and taking into account both present-day lighting engineering and the physiologic characters of the human eye.

3. The level of what might be called the greatest economic advantage; that is, the lighting level beyond which further increases in light probably would not produce increases in health or efficiency consonant with the increased cost. This, it is obvious, is the economist's "point of diminishing returns."

4. The maximum level desirable from considerations of eye physiology only, without reference to economic considerations or to engineering practicability.

This framework provides, it is apparent, 12 different basic figures for lighting levels; one for each of 3 human activities demanding different degrees of light combined with each of 4 grades of lighting considered practicable or desirable. The 12 different foot-candle levels thus decided upon then will be translated by standard methods into watthours for the human activities concerned, into kilowatt-hours for the hypothetical average family and, in turn, for the United States.

The Light Needs of the Eye

The fundamental lighting level necessary for good seeing by the average human eye under any specified conditions (such, for example, as those above referred to) might be determined theoretically in any or all of 6 different ways:

1. Experiments on visual acuity at different levels of illumination.
2. Tests of "work samples" under experimental conditions.
3. Experience under actual working conditions.
4. Figures now accepted by experienced lighting engineers as "good practise" levels.
5. Computations from the characteristics of the light-perceiving elements (rods or cones) in the retina of the eye.
6. Comparison with average outdoor lighting levels in daylight.

Investigations by leading scientists confirm the finding that within reasonable limits of uncertainty,

Based upon "How Much Light?" presented before the Institute's New York Section by Frank W. Smith, *chairman*, lamp committee, National Electric Light Association; E. E. Free, consulting engineer; and Arthur E. Allen, vice-president, Westinghouse Lamp Company, on December 18, 1929, and subsequently brought up to date as of September 18, 1933, by the Institute's committee on the production and application of light, under the chairmanship of J. W. Barker.

visual acuity increases very rapidly with increase of illumination up to between 10 and 20 ft-c. Thereafter there is a lesser but still important increase up to about 100 ft-c. There may be further increases in average acuity for increases of illumination above 100 ft-c but so few experimental investigations have been made that nothing is known with certainty.

A number of "work samples" tests have been conducted and, in addition, investigations made under actual operating conditions. The results all indicate a marked increase in accuracy and speed up to between 20 and 30 ft-c. Beyond 30 ft-c there are still evidences of increase.

Comparisons of indoor lighting levels with outdoor daylight levels under which the eye is supposed to have evolved would be another highly desirable method of attacking the problem could one be certain of the precise conditions of human evolution in the past and of the degree, if any, to which modern life has altered eye characteristics. Full sunlight probably averages about 10,000 ft-c. Ordinary outdoor illumination, in the shade, averages between 500 and 1,500 ft-c depending on the weather. It is probable that primitive man never did any eye work except in levels of illumination well above 100 ft-c. About 500 ft-c may have been a reasonable average for the evolution of skill at close eye work such as the manufacture of stone weapons. Man's eye probably has been developed for accurate seeing under illumination levels between 100 and 500 ft-c.

Table II—Classes of Persons in the Average Family

	Per Cent of Population	Number in Average Family
Infants (under 5 yr)	9.1	0.43
School children (5–14 yr)	19.9	0.93
Working adults	40.0	1.88
Housewives	31.0	1.45
Total	100.0	4.69

In summary, ideal illumination for best seeing is certainly not under 30 ft-c but probably over 100 ft-c. On the basis of scientific studies the prescription of illumination level for the most accurate and easy seeing would be approximately 300 ft-c for any kind of fine work. Based on the facts outlined, the 12 separate levels of illumination for the 3 types of human activity and the 4 illumination grades may be assumed as in Table I.

The Average Family

Quite different meanings are applied in different statistical tabulations to the word "family." According to the census, the average size of the American family is 4.3 persons, while eugenists and persons interested in heredity, compute the size of the American family as from 2.5 to 3.5 persons. For the present inquiry, the idea of the average family is closer to the census definition than to the eugenist definition. But since the census definition leaves over 10,000,000 persons in the United States unaccounted for, it seems fairer to include all persons in the United States in the family computation dividing these persons into hypothetical average families in accordance with the total number of such families.

To provide some idea of the number of such families, the following basic data are available. There are probably at present a total of 23,000,000 occupied dwellings. Another datum is the number of married women and widows in the United States, which total almost 31,000,000. The number of families in the United States according to the census is about 25,000,000.

Taking all these data into account, the present total number of families in the United States is probably about 26,000,000. The total population of the United States is at present a little over 122,000,000 individuals. Dividing this by the estimated number of families, gives for the statistical average family 4.69 persons.

It is now necessary to divide the persons of this statistical average family into classes roughly in accordance with their occupations and habits of living. Four classes have been selected; infants, school children, working adults, and housewives. According to the census of 1930, persons under 5 years of age equal 9.1 per cent of the population. These may be taken as equivalent to the class of "infants." Persons between 5 and 14 years of age equal 19.9 per cent. These may be taken as equivalent to the class of "school children." The adult population, being all those over 15 years of age, equal 71 per cent of the population. It is necessary to divide this percentage into the 2 classes of "workers" and "housewives." In 1926, a normal year, about 40 per cent of the total population were gainfully employed. Assuming this figure and subtracting it from the 71 per cent of total adults leaves 31 per cent for the classification of "housewives."

The 4.69 persons in the statistical average family may then be distributed in accordance with these 4 percentages to yield Table II.

Table III—Light-Hour Needs of Individual Members of Average Family

	Work Illumination	Social Illumination	Utility Illumination
	Daily Person-Hours		
Infants			
Bedroom, etc.		1.00	
School Children			
Homework and reading	1.50		
Meals and social		2.00	1.00
In school	0.50	0.50	1.00
	2.00	2.50	2.00
Working Adults			
Dressing and undressing		0.50	
Work	2.00	3.00	3.00
Meals and social		2.00	5.00
Home reading	0.50		
	2.50	5.50	8.00
Housewives			
Dressing and undressing		0.50	
Work	3.00	2.00	3.00
Meals and social		2.00	5.00
Home reading	0.50		
	3.50	4.50	8.00

Table IV—Light-Hour Needs of "Average Family"

	Persons in Family (From Table II)	Work Illumination	Social Illumination	Utility Illumination
		Total Daily Person-Hours		
Infants	0.43		0.43	
School children	0.93	1.86	2.32	1.86
Working adults	1.88	4.70	10.34	15.04
Housewives	1.45	5.08	6.52	11.60
	4.69	11.64	19.61	28.50

Table V—Computation of Light-Hours Necessary for the Continental United States

	Work Illumination	Social Illumination	Utility Illumination
Daily hours per family (Table IV)	11.64	19.61	28.50
Daily hours per 22,000,000 families	256,080,000	431,420,000	627,000,000
Annual hours per 22,000,000 families, 365 days	93,500,000,000	157,500,000,000	229,000,000,000

Table VI—Light Needs of the Continental United States Expressed in Electric Energy

	Millions of Kilowatthours per Year			
	Work Illumination	Social Illumination	Utility Illumination	Total
Minimum good practise at present	12,300	17,400	40,500	70,200
Minimum recommended levels	24,600	34,800	67,400	126,800
Probable level of greatest economic advantage	41,100	52,200	67,400	160,700
Possible desirable levels from eye consideration only	246,000	174,000	405,000	825,000

The next step is the computation of the needs of the average family for hours of artificial light per day dividing this computation into 3 grades of illumination, "work," "social," and "utility," as referred to previously. The basic assumption is that each individual, whether in his or her working place or merely moving about the house, office, or city, is supposed to be provided with an area of illumination sufficient for the occupation being followed at that moment. These figures, based upon general information plus such statistics as are available for school-child hours, working hours, and so on, are given in Table III.

In computing the figures of Table III account has been taken of the variations of daylight in different parts of the United States for different months of the year and also, so far as possible, of lost daylight in cities due to smoke and close building. A summary for the statistical "average family" is given in Table IV.

This distribution of activities and needed light-hours may now be applied to the total number of families in the United States able to use electric light. There are at present almost 20,000,000 wired homes in the United States. Allowing for extensions of electric service which are economically justifiable, it probably is reasonable to assume a saturation figure of 22,000,000 average families as above defined reachable by electric current for lighting purposes. On this basis the light-hours needed in the continental United States, based upon the preceding assumptions and computations, may be summarized as Table V.

Light Needs in Kilowatthours

The first step in translating these figures from light-hour needs into needs of electricity is the translation from foot-candles into lumens and thence into watts. In theory, it might be sufficient to illuminate only the article looked at; for example, a book under a reading lamp. On this basis relatively few lumens would be required to produce even 100 ft-c. However, the relatively high levels of illumination which the human eye apparently needs cannot be provided satisfactorily without close attention also to the matter of glare. It is probable that future lighting practise will insist more and more on a reasonably even level of illumination for the entire interior of working rooms, offices, and rooms for reading or other close work at home. A fair average of floor space (which is the same as working-level space) in homes and offices is probably about 60 sq ft per individual, which means 4 persons in a room 15 ft square. Taking the usual rule of doubling the needed lumens to compute the generated lumens, this means the necessary emission of 120 lumens, on the average, for each foot-candle of illumination at the level here referred to as work illumination.

For social illumination, while the lighting level is lower, the area which must be illuminated is greater, since 1 or 2 persons frequently occupy a room large enough for 8 or 10. Probably an average illuminated area of 150 sq ft per person is a reasonable assumption for this group of human activities; covering an allowance, also, for the considerable percentage of such rooms left illuminated at this intermediate level while no one is in them. On the same assumption as before this would mean 300 emitted lumens for each useful foot-candle.

For utility illumination the area to be illuminated is again larger and a still larger allowance must be made for rooms, like halls and passageways, which should be illuminated almost continuously even if not occupied. A total of 400 sq ft of illuminated area per person does not seem an excessive allowance, account being taken of the necessity that no dim, unlit corners be left as accident hazards in factories and under similar circumstances. This would equal 800 emitted lumens for each useful foot-candle.

These values now may be converted into electrical energy by the factor of 13.6 lumens per watt given in the 1932–33 report of the lamp committee of the National Electric Light Association. The results are: for work illumination 8.8 watts per foot-candle; for social illumination 22.1 watts per foot-candle; for utility illumination 58.8 watts per foot-candle.

It is now possible to combine Table I, Table V, and the figures just given to compute the country's

needs of light, in kilowatthours per year, on the different bases of illumination and of human activity specified in Table I. The results of this computation, in millions of kilowatthours per year, are given in Table VI.

Saturation

To compute from the figures of Table VI the percentage saturation of the United States, the additional figure needed is the present use of electric energy for light. The latest figures giving actual sale of electric energy for the production of light are those of the census of manufacturers of 1922. At that time the sale of energy for light was 9,982,676,000 kilowatthours per year. This has increased notably since 1922.

One way of computing the increase is from figures prepared annually by federal power commission and giving the total electricity generated for all purposes in the United States. This figure in 1922 was approximately 48 billions of kilowatthours. At present electricity is probably being generated at the rate of approximately 90 billion kilowatthours per year. This is an increase of approximately 100 per cent since 1922. Applying this rate of increase to the approximate 10 billion kilowatthours sold for light in 1922, the present consumption of electricity for light is indicated as approximately 20 billion kilowatthours per year. Consumption of electricity in other directions, especially in transit and railway electrification, probably has increased in somewhat greater ratio than has the lighting load. However, to be as conservative as possible in computing the saturation figures, it is proposed to accept the round figures of 20 billion kilowatthours per year as the present consumption of electricity for lighting purposes in the United States.

Based on this figure and the data of Table VI, the light saturation percentages at present, on the basis of the 4 assumed levels for the use of light, are given approximately in Table VII.

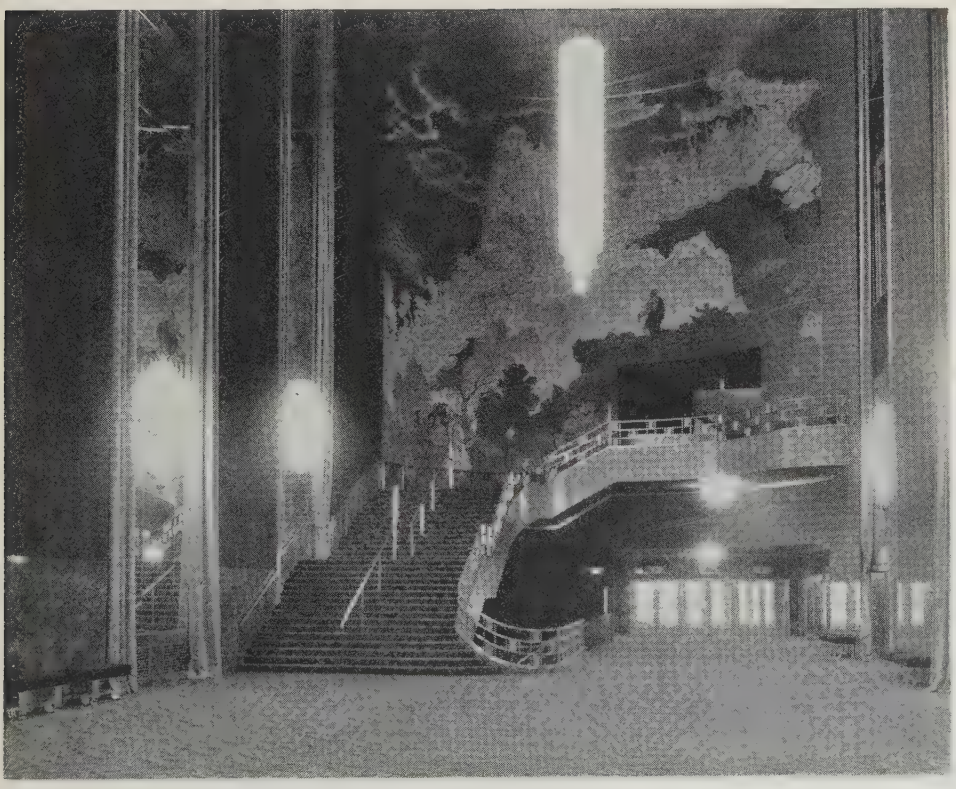
Table VII—Approximate Percentage Saturation in Artificial Light, on Different Bases

Minimum good practise at present	28%
Minimum recommended levels	16%
Probable level of greatest economic advantage	12%
Possible desirable levels from eye considerations only	2.4%

Accuracy of the Computation

There is no claim that these figures are more than very rough approximations, to be published only in the hope that publication may induce the collection more complete and accurate data. The present saturation on the continental United States in artificial light on the basis of a lighting level believed to offer the greatest economic advantage may be as low as 8 per cent or as high as 20 per cent, instead of the 13 per cent figure of Table VII. It seems less important to the lighting industry, however, to reach an exact figure for this percentage than it is to realize that any correct figure must be extremely low.

Lighting of the Grand Foyer of the Radio City Music Hall, New York



LUMINAIRES which are modern in design, simple, and dignified in effect, illuminate the grand foyer of the International Music Hall, part of the Radio City group, New York, N. Y. The 2 large chandeliers, one of which is shown in this view, are each approximately 29 ft long and weigh 2 tons. There is an inner cylinder of heat resisting molded glass, 16 ft long and 2 ft in diameter, surrounded by an outer ring of grooved glass tubes which are also heat resisting. Within the cylinder are 98 outlets with 40-watt lamps. The 6 large wall units are of the same general material, each bracket being designed for 1,300 watts and having a weight of approximately 950 lb. Unusually good illumination is secured on the huge mural.

News

Of Institute and Related Activities

Nomination of A.I.E.E. Officers for 1934 Election Members Invited to Submit Suggestions by Nov. 15

FOR THE nomination of national officers to be voted upon in the spring of 1934, the A.I.E.E. national nominating committee will meet between November 15 and December 15, 1933. To guide this committee in performing its constituted task, suggestions from the membership of course are highly desirable. To be available for the consideration of the committee, all such suggestions must be received by the secretary of the committee at Institute headquarters, New York, N. Y., not later than November 15, 1933. In accordance with the provisions of the constitution and by-laws, quoted herewith, actions relative to the organization of the national nominating committee now are under way.

Constitution

28. There shall be constituted each year a national nominating committee consisting of one representative of each geographical district, elected by its executive committee, and other members chosen by and from the board of directors not exceeding in number the number of geographical districts; all to be selected when and as provided in the by-laws; the national secretary of the Institute shall be the secretary of the national nominating committee, without voting power.

29. The executive committee of each geographical district shall act as a nominating committee of the candidate for election as vice-president of that district, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

30. The national nominating committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The national nominating committee shall name on or before December 15 of each year, one or more candidates for president, national treasurer, and the proper number of directors and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical districts, if received by the national nominating committee when and as provided in the by-laws; otherwise the national nominating committee shall nominate one or more candidates for vice-president(s) from the district(s) concerned.

By-laws

SEC. 22. During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district that by November 1 of that year the executive committee of each district must select a member of that district to serve as a member of the national nominating committee and shall, by November 1, notify the secretary of the national nominating committee of the name of the member selected.

During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district in which there is or will be during the year a vacancy in the office of vice-president, that by November 15 of that year a nomination for a vice-president from that district, made by the district executive committee, must be in the hands of the secretary of the national nominating committee.

Between October 1 and November 15 of each year, the board of directors shall choose 5 of its members to serve on the national nominating committee and shall notify the secretary of that committee of the names so selected, and shall also notify the 5 members selected.

The secretary of the national nominating committee shall give the 15 members so selected not less than 10 days' notice of the first meeting of the committee, which shall be held not later than December 15. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. All suggestions to be considered by the national nominating committee must be received by the secretary of the committee by November 15. The nominations as made by the national nominating committee shall be published in the January issue of ELECTRICAL ENGINEERING, or otherwise mailed to the Institute membership during the month of January.

(*Signed*) H. H. HENLINE, *National Secretary*

October 1, 1933.

Power System Control at Panama Canal Zone

The electric power system serving the Panama Canal Zone is now controlled by 2 dispatchers operating supervisory control equipment which replaces the manual operators and the telephone dispatching formerly used. An average of 3,000 operations per month are performed by this equipment, and operation, especially under emergency conditions, has been improved.

The main power supply for the Canal Zone is at Gatun Dam, where there is a hydroelectric power station of 13,500 kw capacity, with provision for future extension to 22,000 kw capacity. There also is a diesel-electric generating station at Miraflores with 3 units totaling 7,500 kw capacity, used for emergency and as peak load generation. There is now in construction a second hydroelectric station, located at Madden Dam, which will have an initial capacity of 16,000 kw.

Transmission to the various load centers on the Isthmus is over a 2 circuit 3-phase 25-cycle 44-kv transmission line about 46 miles long. A spur line of similar rating and 12 miles long extends to the Madden hydroelectric station which is now under construction. The principal substations are at Gatun and Miraflores, and at the Atlantic and Pacific ends of the canal. A few smaller substations are connected to the transmission lines at intermediate points.

The power apparatus at these various points is remotely controlled and supervised by a supervisory control system manufatured by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and operating over a few small wires similar to those used for telephone purposes. Prompt and accurate response to dispatcher's orders is obtained, and quick sectionalizing of faults and prompt restoration of service under emergency conditions is made possible by this control. Different types of supervisory control are used, depending upon the service to be performed at the different stations; the 2 types in greatest use at the Canal Zone are known as the synchronous-visual and the visicode types.

Bulletin on Industrial Research Laboratories Available. The 5th edition of "Industrial Research Laboratories of the United States Including Consulting Research Laboratories," bulletin 91 of the National Research Council, is now available. This report includes a list of about 1,575 laboratories, including an analysis of the research staff, names of the directors, and type of research activities undertaken. A geographical distribution of these laboratories is included, as well as a subject classification of the laboratory activities. An analysis of some of the information obtained in this bulletin was given in ELECTRICAL ENGINEERING for September 1933, p. 641. The bulletin may be obtained from the National Research Council, 2101 Constitution Avenue, Washington, D. C., at a price of $2.00.

Business Trends Analyzed in Recent Report

Following are quotations taken from the current report of the National Industrial Conference Board, New York, N. Y., which indicate some of the recent trends as determined by that organization's conference of statisticians in industry:

"A decline in general business activity was experienced in August 1933 and the first half of September after a succession of advances from March through July. Between the second week of August and the second week of September productive activity lost further ground.

"Production in the major industries moved generally downward in the last 6 weeks. Automobile output declined in August and the first half of September from the July level of activity. Building and engineering construction on the other hand showed a sharp gain, with sudden increases in public construction contract awards overshadowing declines in residential and non-residential construction. Steel output fell off sharply, although pig iron production advanced. Bituminous coal production gained more than seasonally in recent weeks. Textile production fell off

more than seasonally in August. Electric power output advanced less than seasonally in August and fell off in the first half of September.

"The total distribution of commodities by rail advanced less than a seasonal amount in August as compared with July and tapered off in September, when an additional gain is usually seasonal. Shipments of merchandise and miscellaneous items that reflect the primary distribution of finished goods fell off in August and the early part of September when increases are seasonal. Retail sales by department stores, on the other hand, showed a sharp gain, of more than usual seasonal proportions. Department store prices advanced sharply between July and August.

"Prices of commodities at wholesale advanced again in August and continued to move up during the first half of September. Farm products and foods declined in August as compared with July while textiles, metals, building materials, fuels, and miscellaneous items advanced. Farm products at wholesale showed a tendency to advance during the second week of September. Prices of farm products received by farmers fell off between the middle of July and the middle of August while prices paid by them advanced.

"The cost of living advanced 2.3 per cent between July and August to a level 7.5 per cent above the low point in April and was on a par with the cost of living in August, 1932. Food prices at retail advanced 1.8 per cent between July and August; rents were stationary; clothing advanced 9.5 per cent; fuel and lighting, 2.0 per cent; and sundries, 1.6 per cent.

"Common stock prices in August were slightly lower than in July because the slow upward movement during the month was insufficient to compensate for the drop during the middle of July. Bond prices followed a similar course. During the first half of September the upward movement was cautiously continued. The money market showed a slight downward revision in rates. Increased open market operations on the part of Federal Reserve Banks were in evidence in the first half of September.

"Commercial failures in August showed an upturn in both number and extent of liabilities incurred. The unseasonal increase in number came after several months of unusually low levels. Liabilities incurred, mounting sharply, made up in August for the low levels of preceding months. A slackening in failures was felt in the first half of September.

"Employment in manufacturing industry in August advanced 6.4 per cent over the July level. Factory payrolls advanced 11.6 per cent. In normal years only a slight increase is observed between July and August in employment and payrolls in manufacturing industry. Since the low point in March employment has advanced 30 per cent, payrolls advanced 55 per cent. Preliminary estimates indicate little or no change in weekly earnings per worker in August, a decline in hours almost entirely compensating for a rise in hourly earnings.

"The downturn in business activity in August and the first half of September was largely of the nature of a decline in productive output in outstanding major industries Shipments of freight did not advance in accordance with seasonal expectations. Distribution to the consumer, on the other hand, moved up sharply during the month with department store sales passing seasonal expectations."

Modernization of a Fountain

The fountain in the plaza of the City of San Diego, Calif., presented to the city in 1911 by its mayor, has been modernized. Originally it was lighted by ordinary incandescent lamps placed under glass domes and under pools around the bases of the columns. Water caused trouble with the wiring, and the system was finally disconnected.

Now a motor driven flasher and 20 underwater floodlights, all of General Electric manufacture, have been installed. Four floodlights with clear lenses are in the roof;

8 with alternate green and blue lenses are in the pools below the columns; and the other 8, with alternate red and amber lenses, are under the sprays in the center, with their beams engaging the spray at 5 deg. Each floodlight has a 250-watt Mazda lamp.

Technical Board of Review of PWA

Appointment of 12 members of the technical board of review of the U.S. government's Public Works Administration has been announced by Administrator Harold L. Ickes. This group of engineers will consider the qualifications of particularly difficult or controversial projects which are referred to it by the administration for review and will also serve in a quasi-judicial capacity and hold open hearings on projects when public opposition develops and such hearings are required. It will further fulfill the functions of a court of appeal on request of the administration.

Col. Carey H. Brown will serve as acting chairman of the technical board of review. Other members of the board, none of whom happens to be a member of the A.I.E.E. are as follows:

David C. Coyle, New York, N. Y.
Howard P. Emerson, Washington, D. C.
Harrison P. Eddy, Boston, Mass.
Philip W. Henry, New York, N. Y.
Malcolm Pirnie, New York, N. Y.
Frederick H. Fowler, San Francisco, Calif.
W. H. Horner, St. Louis, Mo.
Richard S. Buck, Crozet, Va.
Samuel A. Greeley, Chicago, Ill.
Clarence A. Dykstra, Cincinnati, Ohio.
Irving B. Crosby, Boston, Mass.

Science Advisory Board Appointed by President

A science advisory board has been created by President Roosevelt to assist the government with its scientific problems. This board will act as a part of National Research Council which was created at the request of President Wilson in 1916. President Roosevelt's executive order says in part "there is hereby created a science advisory board with authority, acting through the machinery and under the jurisdiction of the National Academy of Sciences and the National Research Council, to appoint committees to deal with specific problems in the various departments." The science advisory board will consist of the following members, who are appointed for a period of 2 years:

Karl T. Compton (F'31) *chairman*, president, Massachusetts Institute of Technology.

W. W. Campbell, president, National Academy of Sciences, Washington, D. C.

Isaiah Bowman, chairman, National Research Council, and director, American Geographical Society, New York, N. Y.

Gano Dunn (A'91, F'12, past-president, and life member) president, J. G. White Engineering Corporation, New York, N. Y.

Frank B. Jewett (A'03, F'12, and past-president), vice-president, American Telephone and Telegraph Company, and president, Bell Telephone Laboratories, New York, N. Y.

Charles F. Kettering (A'04, F'14), vice-president, General Motors Corporation, and president, General Motors Research Corporation, Detroit, Mich.

C. K. Leith, professor of geology, University of Wisconsin.

John C. Merriam, president, Carnegie Institution of Washington, D. C.

R. A. Millikan (M'22, HM'33) director, Normal Bridge Laboratory of Physics, and chairman of the executive council, California Institute of Technology, Pasadena.

International Office of Chemistry Organized. Announcement has been made of the organization of the International Office of Chemistry, formed by representatives from the principal countries in Europe, for the purpose of documentation of the large amount of published information in the field of chemistry. It is the aim of this organization to assist in classifying and making more readily available all types of information on chemistry. The office of the organization is 49, Rue des Mathurins Paris 8E, France.

Engineers' Council for Professional Development Now Fully Organized

DURING the year following the organization meeting of the Engineers' Council for Professional Development held October 3, 1932, a definite program has been adopted and the 4 committees necessary for the carrying out of this program have been appointed. Seven national engineering organizations have ratified the plan and are coöperating actively toward its fulfillment. A sound foundation has been laid for the more tangible accomplishments which may confidently be expected to follow.

The Engineers' Council for Professional Development is an organization of tremendous importance to all engineers. It is largely the result of a feeling which has been growing within the professional engineering societies that a joint body could do much toward enhancing the professional standing and the personal welfare of the members of the societies. Paralleling this feeling there have been several efforts working toward the licensing of engineers by state legislation. It was with the hope of coordinating these various impulses that the Engineers' Council for Professional Development was started on its organization. The initial program proposed by the E.C.P.D. Engineers' Council for Professional Development was stated as follows:

"First, to develop further means for educational and vocational orientation of young men with respect to the responsibilities and opportunities of engineers, in order that only those may seek entrance to the profession who have the high quality, aptitude, and capacity which are required of its members;

"Second, to formulate criterions for colleges of engineering, which will insure to their graduates a sound educational background for practising the engineering profession;

"Third, to develop plans for the further personal and professional development of young engineering graduates, and a program for those without formal scholastic training;

"Fourth, to develop methods whereby those engineers who have met suitable standards may receive corresponding professional recognition."

Participating Societies and Committees

The 7 participating societies which have ratified the plan of the Engineers' Council for Professional Development are the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining and Metallurgical Engineers, the American Institute of Chemical Engineers, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners. Each of these societies is represented on the council by 3 men. Representatives of the A.I.E.E. are C. O. Bickelhaupt (M'22, F'28), L. W.W. Morrow (A'13, F'25), and C. F. Scott (A'92, F'25, HM'29).

At the organization meeting, C. F. Hirshfeld (A'05), a representative of the A.S.M.E., was elected chairman *pro tem*, and C. E. Davies, a representative of the A.S.M.E., was elected secretary *pro tem*. The interim executive committee which organized the other committees and developed rules and procedure consists of: J. V. Davies, A.S.C.E.; W. E. Wickenden (A'07, M'13) A.S.M.E.; C. F. Scott (A'92, F'25, HM'29) A.I.E.E.; H. C. Parmelee, A.I.Ch.E.; D. F. Irvin, A.I.M.E.; R. I Rees, S.P.E.E.; D. B. Steinman, N.C.S.B.E.E.; with C. F. Hirshfeld and C. E. Davies, *ex-officio* members.

The personnel of the 4 committees is as follows:

Committee on Student Selection and Guidance. R. L. Sackett, *chairman*, H. P. Eddy, H. N. Davis. O. J. Ferguson (A'05, F'13), T. K. Legaré, V. M. Palmer, and W. B. Plank.

Committee on Engineering Schools. K. T. Compton (F'31), *chairman*, H. A. Curtis, P. H. Daggett (A'08), H. P. Hammond, E. P. Mathewson, A. A. Potter, and H. S. Rogers.

Committee on Professional Training. R. I. Rees, *chairman*, J. C. Arnell (A'28), C. Derleth, Jr., D. S. Kimball, R. A. Seaton, A. D. Smith, and W. B. Updegraff.

Committee on Professional Recognition. C. N. Lauer, *chairman*, J. W. Barker (M'26, F'30), F. M. Becket, F. L. Bishop, H. C. Parmelee, J. P. H. Perry, and D. B. Steinman.

The committee on student selection and guidance has outlined a program of activity, in which it has guarded against the danger of attracting to engineering schools individuals who would not be fitted for the study and practise of engineering.

A report has been submitted by Doctor Compton that his committee on engineering schools has made considerable progress. A subcommittee consisting of Dean Daggett and Professor Hammond is assembling material dealing with the establishment of criterions for engineering schools. The committee also is considering questions of coöperation with engineering schools in the matter of curriculums.

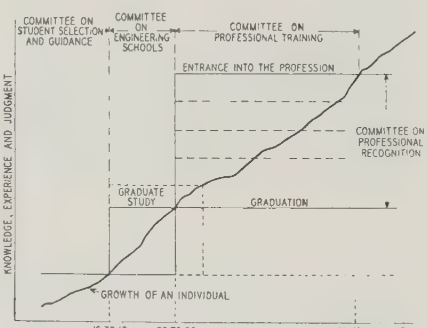


Chart illustrating the fields of activity of the 4 committees of the Engineers' Council for Professional Development. This chart was included in an informal talk presented by L. W. W. Morrow at the annual conference of officers, delegates, and members held in conjunction with the A.I.E.E. summer convention, Chicago, Ill., June 26–30, 1933.

For the committee on professional training, General Rees has reported that items under consideration include a survey of the location of young engineers and of educational facilities available; preparation of an informational bulletin; and a survey of local engineering organizations available for the direct assistance of young engineers.

For the committee on professional recognition, research work has been started bringing together information about the 3 existing standards of professional recognition: membership in engineering societies, professional degrees, and requirements for licensing and registration.

These 4 committees with the coöperation and support of the 7 national engineering organizations have the power to enhance the professional status of engineers. The Engineers' Council for Professional Development aims to coördinate and promote efforts and aspirations directed toward higher professional standards of education and of practise; it aims to promote greater solidarity of the profession and thus secure greater effectiveness in dealing with technical, legislative, social, and economic problems. The aims of the council are ambitious and deserve the attention of engineers throughout the country.

I.C.I. Sessions Postponed Until 1935

Announcement has been made by G. H. Stickney (A'04, F'24) secretary-treasurer of the United States national committee of the International Commission on Illumination that the plenary sessions of the International Commission on Illumination, originally scheduled to be held in Germany in 1934, have been postponed on account of the present world-wide unsettled business conditions. The sessions are now scheduled to be held in Germany in June 1935. It is planned to hold an international illumination congress in connection with these sessions. The American secretariats on factory and school lighting, air craft lighting, and lighting education have their work well along in preparation for the 1935 meetings. Questionnaires have already been circulated by several European secretariats. Interesting papers on lighting questions of modern world interest are being planned.

Line Insulator Contracts for Boulder Dam Awarded

A total of 235,000 disk type porcelain suspension insulators for the transmission line from the Boulder Dam power plant of the federal government at Boulder Canyon, Nev., to the city of Los Angeles, Calif., has been contracted for by the Bureau of Power and Light of Los Angeles. The order was placed with the Ohio Brass Company. The company's insulator plant at Barberton, Ohio, will produce these insulators, while the Mansfield, Ohio, works will supply the malleable iron castings which total some 325 tons.

Delivery of the insulators is to begin this year. Under the terms of the agreement approximately 75 carloads will be delivered before January 1, 1935. As previously announced the contract for the conductors has been awarded to the General Cable

Corporation, and that for the towers was awarded to Tower Builders, Inc., and McClintic-Marshall Corporation. Contracts for 1,256,000 lb of $^1/_4$ in. rolled black copper rods have been placed with the Graybar Electric Company, Ltd., and the Anaconda Wire and Cable Company, of California; these rods will be used as ground counterpoise.

New Observatory to Be Built in Texas

Contract for the design and construction of the new McDonald Observatory on Mt. Locke in southwestern Texas, containing the second largest telescope in the world and exceeded only by the 100-in. telescope on Mt. Wilson in California, has been awarded to The Warner & Swasey Co., Cleveland, Ohio. The company has long been famous for the building of telescopes and precision machine tools. Ambrose Swasey (HM '28) chairman of the board of the company has been active in the scientific world for over 50 years.

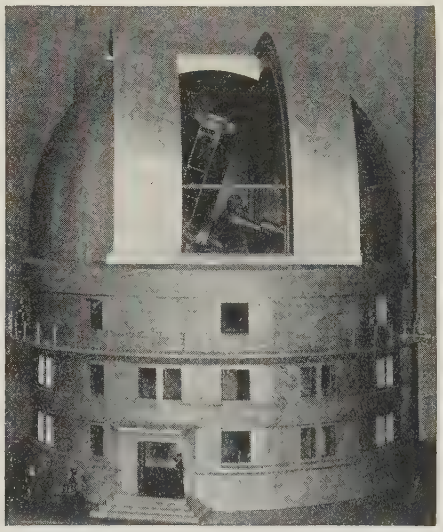
The observatory is being erected as a result of a bequest of the late W. J. McDonald, of Paris, Texas, for the purpose of constructing a telescope and observatory for the University of Texas. A coöperative plan has been worked out whereby the University of Texas will build the observatory and the University of Chicago will supply the trained experts and personnel to operate it. Dr. Otto Struve, director of Yerkes Observatory of the University of Chicago, will be in charge of the McDonald Observatory.

The main features of construction will include steel work of a highly specialized nature, manufacture of optical parts which requires the utmost precision, an intricate system of anti-friction bearings, and a complicated system of electrical control.

The observatory, in which the telescope will be housed, will be a cylindrical steel structure 71 ft high, surmounted by a hemispherical dome 62 ft in diameter. Construction will be of structural steel with special alloy sheet metal covering on exterior and interior, including insulation. The observing floor, where the telescope stands, will be 3 stories above the ground. The 2 lower floors will contain offices, chemical kitchen, library, developing rooms, and sleeping quarters.

The entire structure will be built around the 2 massive piers which support the telescope. These piers alone required 450 tons of concrete and 10 tons of reinforcing steel. The telescope is to be of the reflector type. It will be approximately 26 ft long and its main feature will be a great mirror 80 in. in diameter, and weighing 5,000 lb. The raw material of the mirror will be Pyrex, a type of glass made by the Corning Glass Works, at Corning, N. Y. The grinding and polishing of this mirror will require about $2^1/_2$ years, and will be done at the Warner & Swasey plant in Cleveland. Five secondary mirrors will also be required.

The many movable parts of the telescope and the observatory must be capable of immediate and easy adjustment in spite of their enormous weight. Thus, the dome, weighing 115 tons, must be capable of revolving as desired. Shutters on the dome must be opened or closed at will. Curtains protecting the telescope against wind must also be subject to quick control. The telescope itself must revolve automatically at a speed compensating for the rotation of the earth, in order to keep it trained steadily upon the star under observation. At the same time it must be capable of adjustment at right angles to its axis in order to reach any part of the heavens. In a telescope of this sort there are various observing points, some at the lower end of the telescope, some part way up, and one at its extreme tip. Consequently 2 movable platforms and an observing bridge upon which the astronomer stands must be raised or lowered at will. All of these movements must be made with the utmost precision.



Model of observatory to be constructed for the University of Texas

The result is a complicated system of antifriction bearings and electric control whereby the entire operation can be handled by the observer by means of an electric push button panel. To accomplish this, a wiring system is required which uses approximately 4 miles of electric wire. The observatory will cost approximately $325,000 and will take about $2^1/_2$ years to complete. Work on the project has already begun.

India and the United States Linked by Telephone. One of the transatlantic radio telephone channels between the United States and England recently was linked with a short wave channel connecting London with radio telephone stations near Bombay, India. Since May 9, 1933, regular telephone communication between the United States and India has been available through the coöperation of the American Telephone and Telegraph Company and the British Post Office. In addition to United States telephones, the service embraces those in Canada, Cuba, and Mexico. At the distant end it will for the present be limited to the telephone systems of Bombay and Poona, India, the fifty-second country to be brought within telephone reach of the United States, is the third country of Asia to be included in the network. Connections with Siam and Palestine have already been established. American subscribers may now talk with more than 92 per cent of the world's telephones, as well as with 20 liners on the high seas.

Proceedings of Commission on Illumination Still Available. The United States national committee of the International Commission on Illumination has a few remaining volumes of the recently issued proceedings of the 1931 sessions held in Cambridge, England, September 13–19, 1931. As announced in ELECTRICAL ENGINEERING for March 1933, p. 202–3, these proceedings are in the form of a cloth bound volume of 694 pages illustrated with cuts and charts; some of the material is in French, other parts are in German, and the rest is in English. As long as available, any member of the A.I.E.E. may secure a copy, post and insurance paid (within the United States and Canada), upon the advance payment of $3. This offer also is open to colleges and libraries in the United States. Remittance and shipping instructions should be sent to G. H. Stickney, secretary-treasurer, at Nela Park, Cleveland, Ohio.

Grid Composition of Storage Batteries

The effect of antimony in producing excessive sulphation of negative plates in storage batteries has been known previously, but recent experiments at the Bureau of Standards of the U.S. Department of Commerce, Washington, D. C., as well as other experiments, have shown that the small amounts of antimony released from the positive grids in the course of normal operation of batteries are sufficient to affect the negative plates. A complete account of the work carried on at the Bureau of Standards has been published as research paper No. 567 in the June 1933 number of the Bureau of Standards Journal of Research. A summary of the information given in this paper follows:

Batteries have been made and operated in the laboratory to test the effect of varying the composition of the grids for positive plates. The alloys employed in this work included a series of lead-antimony and lead-cadmium compositions.

The operation of the batteries was observed during 115 cycles of charge and discharge. For the most part, the cycling of the batteries was controlled automatically, but measurements of capacity and plate potentials were made at intervals during the course of the tests.

No large differences in capacity resulted from variations in the antimony content of the positive grids, but grids containing 3 per cent or less of antimony were not as durable as those of customary compositions.

Tests for loss of charge on standing for a period of 114 days showed the loss to be greater in those cells containing the higher

percentages of antimony in the positive grids. The capacity of the cells, with one exception, was limited by the negative plates, however, and these were found to contain measurable quantities of antimony in the active material after completing 115 cycles of charge and discharge.

The percentage of antimony found by analysis in the active material of the negative plates was greater in those cells in which the positive grids contained the greater percentages of antimony. The analysis for antimony was made at the conclusion of 115 cycles of charge and discharge.

Local action produced at the surface of the negative plates was measured by weighing the plates at intervals while they were suspended in solutions of sulphuric acid and maintained at a constant temperature. The plates having the greatest amount of antimony in the active material sulphated the most rapidly. The negative plates from cells in which the positive grids were made of pure lead or the lead-cadmium alloys sulphated much less than the others.

Positive grids of lead-cadmium alloys did not prove to be as durable as the lead-antimony alloys in these experiments. The operation of negative plates was improved, however, by the absence of antimony from the positive grids. Part of the difficulty with the lead-cadmium alloys may have been caused by insufficient experience in using such material in batteries.

Relief From Hay Fever by Air Conditioning. A booklet entitled "Relief From Hay Fever and Other Disorders by Means of Air Conditioning," contains information on the substances, called allergens, which cause the generation of poisonous enzymes in the human body resulting in hay fever and other similar diseases. Methods of avoiding these allergens and of counteracting their effects also are given, special emphasis being placed on the therapeutic value of air conditioning. The booklet is published by the Frigidaire Corporation, Dayton, Ohio. Tables are included which show the relative ability of various hay fever plans to produce pollen, the commoner causes of pollen in a number of different cities, and the locality and time of pollination of the more common plants causing hay fever and asthma.

Booklet on "The Older Employee in Industry." Details of the steps which business executives are taking to solve the problem of what to do about the employee who has grown old in a manufacturing organization are told in a new report of the Policyholders Service Bureau of the Metropolitan Life Insurance Company, entitled "The Older Employee in Industry." This report presents the findings of a broad survey conducted among 5,000 manufacturing companies. Of those replying to questionnaires, 800, which employ more than a million workers, stated that they have programs in operation for dealing with this problem. Details of these plans are tabulated and analyzed in the report. The 2 principal details are, first, discovery of problem cases, and second, decision as to what procedure is to be followed in these cases. In the interest of ready reference and correct summarization, 2 charts are reproduced in the report. A selected reading list also is included. A limited number of copies of the report are stated to be available and as long as this stock permits, readers desiring copies will be supplied by the Policyholders Service Bureau, Metropolitan Life Insurance Company, 1 Madison Avenue, New York, N. Y.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

A Short Cut to Finding $\sqrt{a^2 + b^2}$

To the Editor:

Regarding short cuts to finding $\sqrt{a^2+b^2}$ the transformation given by Prof. W. J. Seeley in ELECTRICAL ENGINEERING for August 1933, p. 583–4, can be written $\sqrt{a^2+b^2} = a\sqrt{\left(\frac{b}{a}\right)^2+1}$, in which a is the larger of the 2 numbers. If $\frac{b}{a}$ represents $\tan\alpha$ then $\sqrt{1+\left(\frac{b}{a}\right)^2}$ represents $\frac{1}{\cos\alpha}$. Therefore K (see eq 10 on p. 584 of W. J. Seeley's contribution) is equal to $\frac{1}{\cos\alpha}$ or $\sec\alpha$. A good table of trigonometric functions is all that is necessary, and one setting only on the slide rule.

Take for example $a = 6$; $b = 4$. Setting 1 of the lower slide scale against 6 we find that $\frac{4}{6} = 0.667 = \tan\alpha$; the corresponding cosine is 0.8321. Against 0.8321 on the upper *red* scale of the particular slide rule illustrated in Fig. 1, we find the answer, 7.21, on the upper scale of the rule.

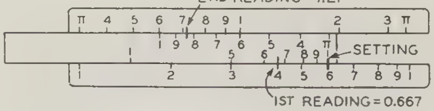


Fig. 1. Setting of slide rule to illustrate example

The trigonometric tables in the "Rubber Handbook" are very handy for this sort of problem.

Very truly yours,
F. V. ANDREAE (A'17)
(Electrical Engineer,
Box 292, Anniston, Ala.)

Skin Effect in Conductors of Given Shape

To the Editor:

The article on "Skin Effect in Rectangular Conductors," by H. C. Forbes and L. J. Gorman in ELECTRICAL ENGINEERING for September 1933, p. 636–9, is of real value, not only in the accurate test results which it presents, but in showing that skin effect measurements can be made very successfully with radio instruments at high frequency.

This emphasizes the attractive possibilities of testing small models of transformer coils, reactor coils, radio coils, cables, built-up busbars, etc., and using the results in designing or for checking engineering formulas. For instance, last year the writer and some students at Massachusetts Institute of Technology constructed a transformer coil model about 6 in. in diameter and 18 in. long, and tested it, without iron, at 3,000 cycles in order to check formulas for eddy current loss in transformers. The results so obtained, if accurately measured, may be used with full confidence with large apparatus and low frequency.

Perhaps a more complete way of making the statement quoted by Forbes and Gorman is that the ratio of a-c to d-c resistance of a conductor, or group of conductors, *of a given shape*, may be determined as a function of the parameter, $P = \sqrt{(8\pi fA/\rho)}$ where f is frequency, A is area of cross section and ρ is resistivity. The factor 8π may be omitted if desired. In other words, for a certain value of P there is a certain value of resistance ratio, and this statement is true at all frequencies, even at one cycle.

It is a quite separate fact that resistance ratio at very high frequencies is proportional to $\sqrt{f}$. It is because of this fact that the square root sign is inserted in the expression for P, so that when resistance ratio is plotted against P, the curve tends to become straight at high frequencies. But the application of high frequency results to large conductors at low frequency is not confined to the straight-line part of the curve, but may be done at any part. Mathematically speaking, this process is reliable in the strictest degree, and extreme caution is not needed in using it. The only precautions are the usual ones that the measurements should be accurate and that when the size of conductor is changed, the shape should remain unchanged, and also that capacitance effects should be avoided.

The bend in some of the curves in Figs. 3 and 4 of the article by Forbes and Gorman, showing parts having 2 different slopes, is of interest. Perhaps something like it occurs in the resistance curve of 2 thin tubes forming a return circuit, as in Fig. 1

shown herewith. The thickness of the tubes is t, which for this curve is 0.01 times the radius. The axial separation of the tubes is 4 times the radius.

Curve I, $R_{\text{isolated}}/R_{\text{d-c}}$ is copied from the left-hand curve of Fig. 3, p. 1384 of "Skin Effect in Tubular and Flat Conductors," by H. B. Dwight, TRANS. A.I.E.E., v. 37, 1918, p. 1379–1400. Curve II, $C = R_{\text{a-c}}/R_{\text{isolated}}$ is copied from the right-hand curve of the figure on p. 337 of "Wave Propagation Over Parallel Tubular Conductors," by Mrs. S. P. Mead, *Bell Sys. Tech. J.*, April 1925, p. 327. Multiplying corresponding values together according to eq 1 of the latter article, Curve III is obtained, showing the a-c resistance of the 2 tubes.

The advantage of separating proximity effect and skin effect is evident in this case. Curve II shows proximity effect, which is due to the crowding of current parallel to the plane through the centers of the tubes. This ratio approaches a maximum 1.155, and practically reaches it at comparatively low frequencies before the skin effect is appreciable. Curve III is what would be shown by a test.

In the case of a thin strap, the effect observed at low and moderate frequencies is "edge effect" due to the crowding of current toward the edges of the strap. A low frequency formula for this is given in eqs 53 and 54 of the previously mentioned paper in the A.I.E.E. TRANS. for 1918. At extremely high frequency, the current begins to crowd also into the skin of the conductor and into the corners. This is calculated by a different formula, and gives rise to a different slope of the curve. The slope of the curve for this extremely high frequency condition has been calculated, and is given in "Skin Effect in Rectangular Conductors at High Frequencies," by J. D. Cockcroft, *Proc. Royal Soc. of Lond.*, Series A, v. 122, 1929, p. 533; the results for different shapes of straps are shown in Fig. 2 and the line following eq 6 of that paper. The slope becomes less as the strap becomes wider and thinner. If the slopes of the right-hand portions of the curves for thin straps in Fig. 3 of the paper by Forbes and Gorman are compared with the results of Dr. Cockcroft's paper, they are found to agree fairly well, especially in

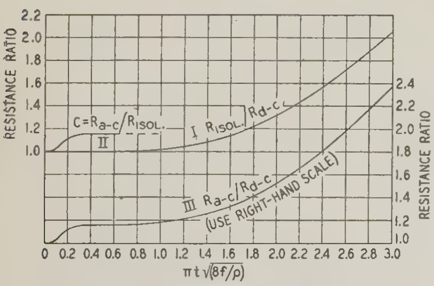


Fig. 1. A-c resistance of 2 thin tubes

the cases of the straps having ratios of 6:1 and 12:1. It seems probable, then, that the lower parts of these test curves for thin straps show "edge effect" and the steeper parts show also "skin effect."

Very thin straps, of width about 200 times their thickness, might show the edge effect ratio approaching a maximum and the curve bending over to the right, before skin effect begins to be noticeable. Some of the test curves of Kennelly and Affel (see *Proc. Inst. Radio Engrs.*, 1916, p. 525) for straps of this type, bend over to the right when plotted on $\sqrt{f}$. This feature has been described in the preceding paragraphs, for the curve for 2 thin tubes.

It is to be noted that Dr. Cockcroft's paper takes account of the radius of curvature of the corners of the strap, which is part of the specification of the shape of the strap, unless it has sharp 90 deg corners.

It would be of value if J. E. Clem would present the formula for eddy current loss in transformer conductors to which he refers in his discussion on the paper by Forbes and Gorman. (See discussion by J. E. Clem, A.I.E.E. TRANS., v. 52, 1933, p. 519.) Information as to the physical dimensions of the copper is also needed for Fig. 1 of his discussion. A skin-effect curve plotted on frequency alone is not a general curve, but is good for only one size of conductor, and he has not stated to what size of conductor his curve applies.

Very truly yours,

H. B. DWIGHT (A'11, F'26)
(Professor of Electrical Machinery, Massachusetts Institute of Technology, Cambridge, Mass.)

Installation and Performance of High Voltage Lightning Arresters

The following 4 letters are discussions of the joint A.I.E.E.-N.E.L.A. subcommittee report on the above subject. The report was presented at the protective devices session of the 1933 A.I.E.E. summer convention held in Chicago, Ill., and was published in full in the June 1933 issue of ELECTRICAL ENGINEERING, p. 394–400.—Editors.

To the Editor:

The West Penn Power Company's experience with arresters in recent years indicates conclusively that moisture in lightning arresters is causing a higher percentage of failures on arresters themselves than on other equipment. The subcommittee's summary of the questionnaire bears out this statement. The manufacturers have made recent improvements, but we feel rather skeptical as to the results after the newer designs have been in service for 2 or 3 years. The manufacturers should include in their routine tests, some arrangement whereby their designs may be subjected to the equivalent of several years of actual service conditions within a short length of time, before they are released for service.

I believe that all of the internal parts of all arresters should be non-corrosive and of such material that the formation of fungus will be impossible.

I believe that the standards should specify that arresters be subjected to all of the insulation and blow-out-fcature tests when mounted on brackets, suspension or otherwise, according to the design. Since the performance of an arrester may be seriously affected by the different types of mounting. I understand that the protective value of an arrester may be greatly changed by the presence of moisture within the arrester; i. e., its initial break-down value may be 5 times its normal rating rather than $2^1/_2$ times. Possibly the manufacturer should consider this and modify their designs so that their protective value should be maintained even if moisture is present.

The West Penn Power Company has just completed the installation of sphere gaps in series with a fuse on the 132-kv side of 39 large single phase transformers. This protective equipment has been mounted on the transformer and connected directly to the bushing terminal and is coördinated with existing arrester protection which has been in service for several years at each station. Failures on apparatus due in some cases to direct strokes and in other cases induced strokes prove to us that this additional protection is necessary and it conforms to recent theory and practise of protective application.

Two direct strokes of lightning, one to the arcing horns of an airbreak switch on the top of the station and the other within one span of the station, lead us to the conclusion that the removal of stationary arcing horns from all our 132-kv airbreak switches which are mounted on the top of our station structure would reduce the possibility of being hit by direct strokes. At 2 of our stations we have installed reserve bus grounding switches. The normally open vertical blades of all of the by-pass airbreak switches are connected to the reserve bus which when grounded provides additional protection against direct strokes at a very little expenditure of money.

During the last 2 years we have installed a number of 20-kv line type arresters close to the high voltage bushings of our older type 25-kv step-down transformer banks. Our 25-kv system is grounded through an 18-ohm resistor in 7 different locations. These 20-kv arresters have been installed with the definite understanding that we would expect the arrester to fail rather than the transformer, and in only one case have we had a bushing flashover on a transformer so protected. We cannot say that the arrester should have prevented this failure. We have had failures on similar transformers in the same general territory where this reduced lightning arrester protection had not yet been installed. During a recent very severe lightning storm we lost 3 of these arresters, one out of a set of 3 protecting one bank and 2 out of a set of 3 protecting a second with the 2 transformer banks operating in parallel. We experienced no failure on the transformers and service was very quickly restored.

I have taken the liberty of mentioning these comparatively recent applications as they indicate our trend and experience in recent arrester protection.

Very truly yours,

H. A. P. LANGSTAFF (A'17, M'27)
(Elec. Engr., West Penn Pwr. Co., Pittsburgh, Pa.)

To the Editor:

It is always difficult to obtain from questionnaires a sufficiently complete story from which to draw conclusions, and yet there are trends which can be detected satisfactorily by this method.

While much progress has been made in the art of determining the performance of lightning arresters since the introduction of the Dufour cathode ray oscillograph (See "Study of Time Lag of the Needle Gap," by K. B. McEachron and E. J. Wade, A.I.E.E. TRANS., v. 44, 1925, p. 832) into this country 10 years ago, yet the conditions of service are such that service experience is of extreme importance. In this connection it is of interest to note that in conclusion No. 8 the statement is made that, of those reported, practically all apparatus failures have occurred on equipment protected by the older types of lightning arresters. Part of this lack of protection may be due to the condition of the older apparatus which, of course, the questionnaire makes no attempt to evaluate. At the same time not only have improvements been made in arresters, but those installed in recent years have in general been in a more favorable position to do efficient work, particularly on account of a better understanding of the

importance of details of installation, such as location, grounds, etc.

There appears to be a definite desire on the part of operators to find some means of determining, by some test, the condition of the arrester after being installed. With modern totally enclosed arresters this is difficult, but effort is being directed toward the solution of this problem and it is hoped that suitable tests may be developed.

It seems to me that the wording of conclusion No. 9 is unfortunate since increased protection always will result from the use of an arrester having a lower maximum permissible voltage rating in those cases where the system grounding permits such use.

The term "protective ratio" does not have a standard definition, but commonly has been referred to as the ratio between the crest of the maximum permissible voltage rating of the arrester and the impulse voltage allowed by the arrester. For modern arresters this value is of the order of 2.5, which means that the arrester holds the impulse to a value 2.5 times the maximum voltage that can be applied safely to the arrester. Because of operating conditions, the arrester cannot be applied to circuits rated at the arrester's maximum rating; therefore, the ratio between the crest of the operating potential and the impulse potential allowed by the arrester is increased. It is of the order of 3.5 for arresters on grounded-neutral circuits and 4.3 for arresters operating on ungrounded circuits. These higher protection levels point to the very great desirability of keeping operating potentials to ground close to normal so that the advantages of better protection may be realized.

With the advent of the entirely enclosed high voltage arrester such as the "thyrite" arrester, difficulty began to be encountered with the entrance of moisture. Corrective measures are being taken to eliminate this difficulty, and it now appears that this type of trouble soon will disappear.

It is indeed gratifying to the manufacturers of lightning arresters to note the degree of performance indicated by this report. It is hoped that still better performance may be obtained in the future and the points of dissatisfaction eliminated. Much has been accomplished, but much yet remains to be done.

Very truly yours,

K. B. McEachron (A'14, M'20)
(Research Engr., Gen. Elec. Co., Pittsfield, Mass.)

To the Editor:

It is regrettable that a report on the performance of arresters must by force of circumstances confine itself to tabulations of troubles alone. When lightning damages apparatus or arresters fail, the occurrence is very evident; but when nothing happens, which is the state the arresters are intended to maintain, there has been in general no telling how much the arresters have had to do with preserving a state of calm during a storm except by statistical comparison such as have been made in the case of distribution circuits. We believe that the value of Table V would be enhanced considerably if specific and detailed data were appended, pertinent to the circumstances surrounding the apparatus failures reported, although it is admitted that the volume of such material would probably be prohibitive in this report. Nevertheless such data would be of great engineering interest. Factors other than the arresters themselves must be given careful consideration if the best possible protection is to be secured. The thought which has been given to coördination and the studies and tests which have been made by operating companies and manufacturers have brought attention to these matters. As a result of this, there is little doubt that improvement can be made in numerous existing installations which either have given trouble or are likely to give trouble, often without replacing or adding to equipment already in place.

It is a consummation devoutly to be wished for to be able to apply a standard arrester to any system anywhere and secure complete protection for the system, but this is as yet confined to the realm of hope and not to fact. So simple a device as an electric light bulb cannot be applied to any circuit, nor will a bulb in the attic illuminate the dining room table.

We believe it would be of great interest if a report were presented at some time in the future giving detailed data on cases of trouble experienced, describing the corrective measures applied, and the results secured, such as has been done in several papers dealing with distribution circuit protection. Operating experience with equipment which is coördinated either on the basis of impulse data on the separate pieces of apparatus, or as a result of actual impulse tests, such as have been carried out by a few companies, would be most interesting. It is unfortunate that in the present state of the art it is not possible to include in Table V a column giving the number of cases of equipment damage or of outages which were prevented by arresters.

In the text of the report, the statement is made that it is recommended that arresters be installed as close as possible to the equipment to be protected with tap and ground leads not longer than 100 ft, "particularly in the higher voltage classes." We believe some misunderstanding exists in this matter. All other conditions being equal, the importance of length of the protective circuit varies inversely as the voltage class; in other words, it is particularly important that leads be short in the low voltage classes. For a given surge, double arrester voltage, for instance, will be reached with much shorter circuits between arrester and apparatus or through the arrester and ground connections, in the low than in the high voltage classes. Distribution transformer protection by the 3-point method or by interconnection (of primary arrester ground and grounded secondary neutral) is a pointed case. It is to be recommended particularly in the low voltage classes that especial pains be taken to keep the protective circuit as short as possible, and in these, distances of less than 100 ft are advisable.

Very truly yours,

Edward Beck
(Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.)

To the Editor:

Experience with over 33,000 arresters on the 4-kv distribution system of the Commonwealth Edison Company shows that most of the failures can be assigned to mechanical weakness. Within the past year, the hazard of moisture entrance has been recognized by some of the leading manufacturers of arresters. Moisture not only leads to complete failure, but it also is a primary cause of corrosion of metal parts which, if the arrester does not fail, causes leakage to ground with resulting radio interference. Where the release of gas pressure through vents is not essential to the operation of the arrester, the housing should be hermetically sealed.

Part of conclusion No. 7 and all of No. 8 do not agree with our findings pertaining to 3-kv arresters. The average performance of 3 modern arresters shows that their annual rate of removal due to all causes has been about 0.14 per cent, and the annual rate of failures of transformers protected by these types for the same period of years has been 0.38 per cent due to lightning; while the corresponding rate of removal for 3 old types has been 1.25 per cent, and the rate of failures of transformers protected by these old types has been 0.43 per cent due to lightning. These data indicate that modern 3-kv arresters are less susceptible to damage than old arresters and also that they afford better protection to the transformers.

Very truly yours,

Herman Halperin (A'21, M'26)
(Cable Research Engr., Engg. Dept., Commonwealth Edison Co., Chicago, Ill.)

Standards

Welding Standards Approved as American Standards

On September 6, 1933, the American Standards Association gave its formal approval to the standards for "Resistance Welding Apparatus" and "Electric Arc Welding Apparatus." The approved standards are revisions of former A.I.E.E. standards Nos. 38 and 39, these revisions having been developed by a sectional committee working under the rules of procedure of the A.S.A. It is expected to issue the revised editions in the near future.

Graphical Symbols Approved as American Standards

The A.I.E.E. reports on proposed standards for graphical symbols, Nos. 17*g2*, 17*g3*, and 17*g5*, that is, "Graphical Symbols Used for Electric Power and Wiring," "Graphical Symbols Used in Radio," and "Graphical Symbols Used for Electric Traction Including Railway Signaling" were approved with certain revisions as American tentative standards by the American Standards Association on September 1, 1933. The revisions relate to certain conflicts of symbols which exist in the 3 fields covered and which it proved impossible to eliminate. It is expected revised editions of the pamphlets will be issued in the near future.

Standards Approved for Constant Current Transformers

The standards for "Constant Current Transformers, Moving Coil Type" have been approved by the American Standards Association as American standard. These standards comprise a revision of the A.I.-E.E. standard for constant current transformers of the moving coil type (A.I.E.E. standard No. 12). The standards were approved by the American Standards Associa-

tion as existing standards and consigned to the new sectional committee on transformers for revisions.

Specifications for Code Rubber Approved

The American Standards Association has approved "Standard Specifications for Code Rubber Insulation for Wires and Cables for General Purposes" (C8.11–1933) as American Standard. These specifications were prepared by the sectional committee on insulated wires and cables (C8) which is under the sponsorship of the electrical standards committee.

The specifications apply to the insulation for electric wire and cable of the grade known to the electrical trade as "code." They are divided into the following parts: workmanship; properties, such as thickness of insulation, chemical, physical, and electrical properties; and measurements and tests, such as dimensional measurements, chemical, mechanical, and electrical tests.

Engineering Foundation

The Alloys of Iron and Silicon

In a 457-page book entitled "The Alloys of Iron and Silicon," a comprehensive review and a critical appraisal of the known facts on the alloys of iron and silicon, and on the effects of silicon on steel and special cast iron, are given. This monograph has been prepared by Alloys of Iron Research, which was organized late in 1929 by The Engineering Foundation, research organization of the 4 national societies of civil, mining and metallurgical, mechanical, and electrical engineers. Alloys of Iron Research was organized after 3 years of preliminary activities, to review and appraise critically all of the research on iron and its alloys reported in the technical literature of the world. The work has progressed to the stage where most of the important journals in English, German, French, and Swedish, from 1892 to date, have been gone over thoroughly, and all data of importance abstracted and classified. The files now contain more than 12,000 critical abstracts, from nearly 5,000 technical papers. These are being reviewed primarily to use as a basis for a series of monographs on alloys of the element iron with 38 of the 92 chemical elements. The first monograph, "The Alloys of Iron and Molybdenum," was published in December 1932. The second volume of this series, "The Alloys of Iron and Silicon," now is available. A critical résumé of all data on steel and cast iron containing silicon as an important alloy is included in this book. A summary of the types of alloys discussed in the book follows.

In addition to the common steels cast irons which are made in enormous tonnages each year and used in construction and similar purposes, are the alloy steels and alloy cast irons containing in addition to the chemical element iron one or more of a large number of special elements such as manganese, silicon, nickel, chromium, vanadium, tungsten, and molybdenum. The higher cost of alloy steels and irons frequently is justified by their superior properties. Among the many types of alloys, the iron-silicon group is among the most important. There are 3 classes of iron-silicon alloys which are essential to modern industrial civilization each class being a development of the past 25 or 30 years. These classes are the silicon structural steels, the silicon electric steels, and the silicon acid-resisting irons.

Silicon Structural Steels

The silicon structural steels combine relatively high strength with a cost but slightly greater than that of ordinary structural steel. In some types of construction, especially in large bridges, the use of silicon structural steels makes possible a stronger structure with no increase in weight, or a lighter structure with no decrease in strength. The silicon structural steels were first used widely in Germany and in England; as early as 1907 silicon steel was used in the construction of the ocean liners Lusitania and Mauretania. Tests made at that time showed that the silicon structural steel had a strength 50 to 75 per cent greater than the steel commonly used for ship construction.

In the United States silicon structural steel has been widely used, especially in the past 10 years, for large bridges. In the George Washington Memorial bridge, lately constructed across the Hudson River, $^1/_3$ of the total steel used or, if the cables are not considered, nearly 50 per cent of the total steel, contains silicon as an alloy.

Silicon Electric Steel

Silicon structural steel, although very important on account of its high strength and low cost, is not indispensable. There are other alloy steels which have equally good properties, but which cost more. There is, however, one material, silicon electric steel, which is indispensable and without which our civilization could not have progressed to its present state of development. The invention of silicon steel, which was later to be used in the construction of electrical machinery, was the result of epochal research work carried out by Sir Robert Hadfield in England during the years 1880 to 1895, in which an extensive series of new steels was developed. It was not until after 1900 that it was discovered that silicon steel had remarkable electric and magnetic properties. Credit for the discovery of these properties and for the development of silicon electric steel must go to a large number of American, German, and British scientists who, working independently, perfected the new material so that by 1915 a complete revolution in the manufacture of electrial machinery had taken place. This development is still going on in the research laboratories of the world and is completely summarized and critically discussed in "The Alloys of Iron and Silicon."

The value of silicon electric steel to our civilization cannot be overestimated. It affects directly or indirectly every individual in the civilized world. By the use of this steel in electric machinery energy losses were cut in half; the saving to the consumers in the United States alone is estimated conservatively at more than $10,000,000 a year. In the past 20 years users of electric current throughout the civilized world have saved nearly $500,000,000.

Silicon Acid-Resisting Irons

In another very important field, the chemical industry, an alloy of iron and silicon is indispensable. It is used in the manufacture of sulphuric acid and nitric acid, which are raw materials for a large number of fertilizers, for nearly all of our explosives, and for many other chemicals and drugs. Until 20 years ago the chemical industry was forced to use expensive platinum and fragile glasware or stoneware for the manufacture of sulphuric acid and nitric acid. In 1912 it was discovered, almost simultaneously in the United States, England, and Germany, that by adding one part of silicon to 6 parts of iron, melting this mixture, and pouring into castings, a material could be obtained which was unaffected by either of these strongly corrosive acids. The result of this discovery was far-reaching; it enabled the manufacture of explosives to be expanded rapidly enough to satisfy the wartime demand, and it so reduced the cost of all chemicals which use these acids as raw materials, including many of the fertilizers, that the chemical industry rapidly attained a position of great importance in our industrial civilization.

All of the research work of the world on silicon structural steels, silicon electric steels, and silicon acid-resisting iron has been reviewed and summarized in "The Alloys of Iron and Silicon." Included also in the book is a complete discussion of the pure alloys of iron and silicon of great importance to the scientist who, by further theoretical and experimental study of these basic facts, may advance our knowledge of alloy steels still further. The book puts at the disposal of the engineer, metallurgist, steel worker, foundryman, and scientist information now scattered through volumes of journals and textbooks in many languages.

Data on manufacture, properties, and uses of the different steels is given. Following a review of previous investigations on the binary iron-silicon alloys, the ternary iron-silicon-carbon alloys, and more complex systems, are a summary and new phase diagrams of the binary and ternary systems. Conflicts in the data have been outlined and attention has been called to existing gaps in the various systems so that the need for further research will be more readily apparent.

"The Alloys of Iron and Silicon" by E. S. Greiner, J. S. Marsh, and Bradley Stoughton, has been published for The Engineering Foundation by the McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y., and can be obtained at an introductory price of $4.00. It is stated that the regular price will be $5.00. The book contains 457 pages, 6x9 in., with 146 tables and 124 illustrations.

Personal Items

D. M. Simmons (A'22, M'26, F'28) chief consulting engineer of the General Cable Corporation, New York, N. Y., has been appointed chairman of the Institute's technical committee on power transmission and distribution for the year 1933–34. He was born in New York, N. Y.; and graduated from Princeton University in 1911, with the degree of bachelor of arts. In 1913 he received the graduate degree of electrical engineer from the same institution. In that year he joined the Standard Underground Cable Company; with the exception of $2^1/_2$ years during the World War Mr. Simmons has been continuously with the Standard Underground Cable Company and its successor organization, the General Cable Corporation, which was organized in 1927. Throughout this period he has been engaged in engineering problems in connection with power transmission and distribution. Until 1917, Mr. Simmons was in charge of the Pittsburgh, Pa., research laboratory of the company. He then was in the U.S. Army during the War, becoming major on General Pershing's staff of the American Expeditionary Forces. In 1919 he returned to the Pittsburgh office of the Standard Underground Cable Company, doing general engineering and executive work, in charge of all company patents, and doing consulting engineering work with the power companies, especially in connection with power transmission by underground cables at very high voltages. For many years he has been in charge of the development of high voltage joints and jointing methods. He was appointed development engineer of the company in 1923, and in 1928 director of high voltage engineering for the General Cable Corporation in New York. In 1930 he was appointed to his present position of chief consulting engineer. Mr. Simmons has taken out a considerable number of patents in this country and abroad, and has written numerous technical articles for scientific and engineering journals and societies. He has been active in the Institute for a number of years, having been a member of the executive committee of the Pittsburgh Section for several years, chairman of the meetings and papers committee of that Section during 1925, and chairman of the Pittsburgh Section 1926–27. He is now a member of the executive committee of the New York Section, and a member of the midwinter dinner-dance committee. He also has been a member of the Sections committee of the Institute, and since 1930 a member of the committee on power generation and distribution. He has served as a member of many subcommittees of the National Electric Light Association and for the past 2 years has been president of the Insulated Power Cable Engineers Association. He is a member of the Institution of Electrical Engineers (London), Société Française des Electriciens; Verband Deutscher Electrotechniker; Associazione Elettrotecnica Italiana (Milano). He is a member of the University Club and the Princeton Club of New York, the Allegheny Country Club, and the Edgeworth Club in Sewickley, Pa.

H. W. Leitch (A'98, M'13) associate chief operating engineer of The New York Edison Company and of The United Electric Light and Power Company, New York, N. Y., has been appointed chairman of the Institute's committee on power generation for the year 1933–34. Mr. Leitch was graduated from the Polytechnic Institute of Brooklyn (N. Y.) with the degree of B.S. in E.E. and later received his E.E. degree from the same institution. He has been identified with large generating stations since 1902. He was one of the original operators of the 74th Street station of the Interborough Company and subsequently was connected with the Waterside stations of The New York Edison Company, successively as system operator, chief operator, and assistant superintendent. He entered the employ of The United Electric Light and Power Company in 1913 as electrical superintendent and later was appointed the first superintendent of the Sherman Creek station, organizing the force that put that station into operation. In 1920 he was made superintendent of power plants and later general superintendent in which capacity was included approval of design and general charge of construction and operation of both Sherman Creek and of the new Hell Gate station. In 1932 he was appointed to his present position. Mr. Leitch has served the Institute as a member of its committee on safety codes 1927–29, and has been a member of the power generation committee since 1929. He is a member of the American Society of Mechanical Engineers, and for several years was a member of the prime movers committee of the National Electric Light Association, during which time he served successively as chairman of the subcommittees on boilers, superheaters and economizers, and condensing equipment.

E. S. Lee (A'20, M'28, F'30) engineer-in-charge, general engineering laboratory General Electric Company, Schenectady, N. Y., has been appointed chairman of the Institute's membership committee for the year 1933–34. Biographical sketches of Mr. Lee appear in Electrical Engineering for January 1933, p. 62, in connection with his nomination as a director of the Institute, and in Electrical Engineering for February 1932, p. 140, at the time of his appointment to the position of engineer-in-charge of the general engineering laboratory of the General Electric Company.

L. A. Doggett (A'13, M'16) professor of electrical engineering, Pennsylvania State College, State College, Pa., has been appointed to the chairmanship of 2 of the Institute's committees for the year 1933–34. These committees are the Student Branches committee and the education committee. He was born in Boston, Mass. In 1908 he received the degree of bachelor of arts from Harvard University, and in 1910 received the degree of M.E.E. from the same institution; in 1930 he received an E.E. degree from the Pennsylvania State College. From 1910 to 1913 he was instructor at the Harvard Engineering School, assisting Prof. C. A. Adams (A'94, F'13, member for life, and past-president), and Prof. A. E. Kennelly (A'88, F'13, member for life, and past-president). The next 10 years were spent as professor of electrical engineering in the post-graduate school of the U.S. Naval Academy, Annapolis, Md., specializing in the teaching of the various applications of electricity on naval ships. During this period he served as a member of the Institute's technical committee on marine application, 1917–19. From 1923 to the present time he has been professor of electrical engineering at the Pennsylvania State College. Professor Doggett spent the sum-

D. M. SIMMONS

H. W. LEITCH

E. S. LEE

L. A. DOGGETT

Bachrach Photo

J. W. BARKER

JOSEPH SLEPIAN

R. N. CONWELL

W. B. KOUWENHOVEN

mer of 1912 with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.; during the summer of 1918 he was attached to the U.S.S. Arizona; and in the summer of 1927 was with the General Electric Company. He has served the Institute as councilor of the Student Branch at Pennsylvania State College from 1926 to date, as chairman of the Middle Eastern District committee on Student activities in 1928, and as a member of the Institute's committee on education in 1924–25. He has contributed several papers and discussions to the Institute, and to many technical and educational periodicals.

H. C. Abell (A'03) formerly vice-president of the Electric Bond and Share Company, New York, N. Y., and president of the National Power and Light Company, New Orleans, La., and director and officer in several other companies of the Bond and Share group, has resigned all offices and directorates in this group, and is retiring from active business. Following graduation from Armour Institute of Technology, Chicago, Ill., in 1897, he became an apprentice with the Canadian Pacific Railway in 1889, and later served with the Belding Motor Company of Chicago, the Canadian General Electric Company, the Anchor Line, and the International Navigation Company. Following service in the Spanish-American War, he became associated with Emerson McMillin and Company in the Supervision of public utilities, and later served with the American Light and Traction Company. Mr. Abell has served the National Electric Light Association as treasurer, and is a past-president of the American Gas Association.

R. N. Conwell (A'15, F'31) transmission and substation engineer, Public Service Electric and Gas Company, Newark, N. J., has been appointed chairman of the Institute's technical program committee for the year 1933–34. A biographical sketch of Mr. Conwell was given in Electrical Engineering for July 1932, p. 528, in connection with the award of the 1931 A.I.E.E. national prize for best paper in engineering practise which was made to him and his co-author, H. S. Warren (A'03, F'13).

Joseph Slepian (A'17, F'27) consulting research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed chairman of the Institute's technical committee on electrophysics for the year 1933–34. A biographical sketch of Doctor Slepian was given in Electrical Engineering for August 1932, p. 600, in connection with his receiving the John Scott Medal for his "discoveries in the field of the deionization of gases and fundamental and outstanding inventions involving these discoveries."

W. B. Kouwenhoven (A'06, M'22, past vice-president) professor of electrical engineering, and assistant dean, The Johns Hopkins University, Baltimore, Md., has been appointed chairman of the Institute's technical committee on instruments and measurements for the year 1933–34. Biographical sketches of Doctor Kouwenhoven appear in Electrical Engineering for July 1932, p. 529–30, and for January 1931, p. 54. The latter item appeared in connection with his nomination as vice-president of the Institute from the Middle Eastern District.

J. W. Barker (M'26, F'30) dean of the school of engineering, Columbia University, New York, N. Y., has been appointed chairman of the Institute's technical committee on production and application of light for the year 1933–34. A personal item regarding Dean Barker was given in Electrical Engineering for November 1932, p. 817, in connection with his election to the presidency of the Illuminating Engineering Society for the year beginning October 1, 1932.

D. C. McClure (A'16) formerly vice-president in charge of operation, Central Public Service Corp., Chicago, Ill., was recently elected president of the Central Illinois Electric and Gas Company, Rockford, Ill. This company is now controlled by the Consolidated Electric and Gas Company, and managed by Stone and Webster, Inc. All operations of the Consolidated Electric properties in Illinois and northern Michigan are under Mr. McClure. He is a past-president of the Rocky Mountain division of the former National Electric Light Association.

E. G. Fox (A'12, M'20) who has been associated with the Leningrad staff of Freyn Engineering Company, Chicago, Ill., has returned to the United States and will resume his activities with this company in the United States. For the past 5 years Mr. Fox has been identified with the power and electrical phases of engineering work in the Soviet Union, in connection with the development of the steel industry in that country.

H. B. Bryans (M'17, F'18) vice-president of the Philadelphia Electric Company, Philadelphia, Pa., in charge of operation, was elected president of the Pennsylvania Electric Association at the meeting held early in September at Bedford Springs, Pa. Mr. Bryans has engaged in various activities of the Pennsylvania Electric Association, the National Electric Light Association and the Pennsylvania Gas Association.

Llewellyn Evans (A'07, M'20) superintendent of lighting, city of Tacoma, Wash., has been appointed consulting technician for the Muscle Shoals project of the federal government. This appointment has been made by Dr. A. E. Morgan, administrator of the federal agency directing the Tennessee development. Mr. Evans has been granted a leave of absence of from 3 to 6 months by the Tacoma light and power department.

R. A. Monroe (A'30) formerly hydraulic engineer and specialist in transmission and hydroelectric engineering for the Aluminum Company of America, Pittsburgh, Pa., is now with the U.S. Bureau of Reclamation at Denver, Colo. Here he will have charge of the structural and mechanical design of hydroelectric plants.

I. H. Sclater (A'08, F'27) formerly assistant engineer, power transformer department, General Electric Company, Pittsfield, Mass., has been appointed engineer of the power transformer engineering department of the company. He has been with the company since 1906, and has been at the Pittsfield works since 1913.

H. L. Thomson (A'21) formerly superintendent of lighting, Hartford Electric Light Company, Hartford, Conn., has been appointed meter and appliance engineer for this company. He recently has conducted researches in connection with the development of electric water heating and rental type electric ranges.

A. L. Kimball (A'15) formerly research engineer for the General Electric Company, Schenectady, N. Y., has been transferred to the engineering general department. Here he will assist all design engineering departments of the company on problems involving

ventilation, vibration, and noise, coöperating closely with the laboratories.

F. B. Jewett (A'03, F'12, and past-president) vice-president, American Telephone and Telegraph Company, and president, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed by President Roosevelt to be a member of the science advisory board of the National Research Council for a term of 2 years.

C. F. Kettering (A'04, F'14) vice-president, General Motors Corporation, and president, General Motors Research Corporation, Detroit, Mich., has been appointed by President Roosevelt to be a member of the science advisory board of the National Research Council for a term of 2 years.

R. A. Millikan (M'22, HM'33) director, Norman Bridge Laboratory of Physics, and chairman of the executive council, California Institute of Technology, Pasadena, has been appointed by President Roosevelt to be a member of the science advisory board of the National Research Council for a term of 2 years.

Vladimir Karapetoff (A'03, F'12, and life member) professor of electrical engineering, Cornell University, Ithaca, N. Y., has been appointed a lieutenant commander in the Naval Reserve of the U.S. Navy. He is assigned to the volunteer naval reserve for engineering duties of special service.

E. E. Hinrichsen (A'07) formerly a member of the technical staff of the Bell Telephone Laboratories, Inc., New York, N. Y., retired from service August 1, 1933. He had completed over 30 years of service with the companies of the American Telephone and Telegraph Company system.

Gano Dunn (A'91, F'12, life member, and past-president) president, J. G. White Engineering Corporation, New York, N. Y., has been appointed by President Roosevelt to be a member of the science advisory board of the National Research Council for a term of 2 years.

W. H. Tierney (A'25) formerly superintendent, Seattle Service Shop, General Electric Company, Seattle, Wash., has opened a contracting business specializing in power plant engineering and electrical engineering in Seattle.

F. M. Gentry (A'26) formerly public utility specialist, Tri-Continental Corporation, New York, N. Y., has been appointed manager of the public utility department of C. W. Young and Company, Inc., investment managers, New York.

K. T. Compton (F'31) president, Massachusetts Institute of Technology, Cambridge, has been appointed by President Roosevelt to be chairman of the science advisory board of the National Research Council for a term of 2 years.

A. T. Clark (A'11) superintendent of rolling stock and shops, The United Railways and Electric Company of Baltimore, Md., has been nominated for president of the American Transit Engineering Association for the coming year.

F. F. Brand (A'10, M'18) formerly managing engineer of the power transformer department of the General Electric Company, Pittsfield, Mass., has been appointed assistant to the manager of the Pittsfield works in charge of engineering.

G. C. Hecker (A'11, M'16) general secretary, American Electric Railway Association, New York, N. Y., has been nominated secretary-treasurer of the American Transit Engineering Association for the coming year.

W. R. McRae (M'17) superintendent of rolling stock and shops, Toronto Transportation Commission, Toronto, Canada, has been nominated to serve on the executive committee of the American Transit Engineering Association for the coming year.

T. C. Wright (A'28) has been elected president of the Otter Tail Power Company, Fergus Falls, Minn., to succeed his father, V. A. Wright, who becomes chairman of the board of directors.

D. L. Smith (M'27) electrical engineer for the Chicago Rapid Transit Company, Chicago, Ill., has been nominated first vice-president of the American Transit Engineering Association for the coming year.

L. B. Stacey (M'29) district manager, Packard Electric Company, Vancouver, B.C., Canada, was elected a member of the executive committee of the Vancouver Electric Club at its recent annual meeting,

Obituary

George Clinton Ward (M'24) president of the Southern California Edison Company, Ltd., Los Angeles, Calif., died September 11, 1933, in Los Angeles. He was born at White Plains, N. Y., in 1863, and was educated at Philips Academy, Andover, Mass. Between 1882 and 1902 he was location and construction engineer for the New York, West Shore and Buffalo Railroad, Erie Railroad, New York Central Railroad, Delaware and Hudson Railroad, and Mohawk and Malone Railroad. Between 1902 and 1911, he was associated with H. E. Huntington in the Pacific Electric Railway and the Los Angeles Railway. Between 1911 and 1917, he was president of the Pacific Light and Power Corporation. When that company merged with the Southern California Edison Company in 1917, he became vice-president in charge of construction and operation of the Edison company and continued in his position until being advanced to that of executive vice-president in 1928. In 1931 he became senior vice-president of the company, and on the death of Russell H. Ballard in 1932, he was appointed president. Doctor Ward has contributed much to the physical and economic growth of southern California, through the development of a large supply of electric energy. In 1911 he made the first study of the hydroelectric power resources of the High Sierra and under his direction the initial undertaking of transmitting electric power from Big Creek on the San Joaquin River to southern California was successfully completed. Spectacular achievements of the High Sierra construction program, which he managed almost continuously from 1911 until its completion in 1928, were the construction of a railroad through the granite gorge of the San Joaquin the creation of 3 huge water storage reservoirs, drilling of the 13-mile Florence Lake tunnel through granite near the summit of the Sierra, the construction of the largest group of high-head hydroelectric plants in the world, the construction of a 250-mile 220,000-volt transmission system to bring the electric energy to southern California, and the installation of a large amount of steam-electric generating capacity near the load centers. Doctor Ward has been honored on many occasions. In 1925 the United States Chamber of Commerce presented him with a bronze medallion commemorating the completion of the Florence Lake tunnel. In 1927, he was awarded the honorary degree of doctor of engineering by the University of Southern California, and in 1928, he received the honorary degree of doctor of science from Oberlin College, Ohio. In 1933 he was made an honorary life member of the Los Angeles Engineers' Club. Doctor Ward was an associate member of the board of trustees of California Institute of Technology, Pasadena, and an honorary member of the American Society of Civil Engineers. He was a member of several clubs, including the California Club, Jonathan Club, Sunset Club, and Zamorana Club.

Burton Hotchkiss Brooks (M'27) assistant division manager of the New York Telephone Company, Plattsburgh, N. Y., died August 18, 1933. He was born at Meriden, Conn., in 1875. In 1897 he graduated from Cornell University, Ithaca, N. Y., with the degree of M.E. in E.E. Between 1899 and 1901, he was employed by the Reserve Construction Company, Cleveland, Ohio, in their engineering department on the work of constructing telephone plants in Ohio. Between 1901 and 1902 he was engineer in charge of all construction and maintenance work of the Cuyahoga Telephone Company at Cleveland, Ohio, and between 1902 and 1904 was engineer in charge of the design and construction of the complete plant of the Dayton (Ohio) Home Telephone Company. Between 1904 and 1907, he was chief engineer in charge of the construction of the plant of the Columbus (Ohio) Citizens Telephone Company, which involved changing the system from manual to full automatic. Between 1907 and 1908 he was chief engineer of the Electric Construction Company of St. Louis, Mo., in

charge of the design and construction of the property of the Home Telephone Company of Detroit, Mich. During most of 1909, he engaged in consulting engineering, and between 1910 and 1914 was chief engineer of the United States Telephone Company of Ohio, being also chief engineer of the Columbus Citizens Telephone Company and the Dayton Home Telephone Company during the same period. During 1913 and 1914 he also was chief engineer of the Toledo (Ohio) Home Telephone Company. Between 1914 and 1921 he was chief engineer of the Ohio State Telephone Company, with headquarters at Columbus, in charge of all engineering, construction and maintenance of its properties. In 1921 he became vice-president and general manager of the Mountain Home Telephone Company (later called the Northern New York Telephone Corporation) which owned and operated the long distance telephone system of northern New York State. In 1932, when the Northern New York Telephone Corporation was merged with the New York Telephone Company, Mr. Brooks was appointed assistant division manager at Plattsburgh, for the latter company. Mr. Brooks was active in the affairs of Plattsburgh, having been president of the Y. M.-C. A., the Physicians Hospital, and the Chamber of Commerce. For many years he served the latter organization as chairman of the committee on publicity.

William Augustus Bucke (A'02, M'13) manager of the apparatus sales department, Canadian General Electric Company, Ltd., Toronto, Ont., Canada, died June 23, 1933. He was born in Sarnia, Ontario, Canada, in 1873. In 1894, he graduated from the School of Practical Science in Toronto, and in 1895 received the degree of bachelor of applied science from the University of Toronto. Between 1896 and 1900, he was with the Royal Electric Company of Montreal, first being in the testing department for one year, then erecting engineer for 3 years, and then a few months as agent. When this company was absorbed by the Canadian General Electric Company, Ltd., in 1901, Mr. Bucke was transferred to the staff of the Toronto district office of the latter company. In 1907 he became manager of the Toronto district office. Upon the formation of the apparatus sales department in 1919, Mr. Bucke was appointed manager, holding this position until his death. He was a past-president of the Toronto Engineers' Club, and was a member of the Toronto Electric Club and The Engineering Institute of Canada. He also was a member of the Senate, University of Toronto, Empire, Canadian, and National Clubs, and the Mississauga Golf Club.

John E. Sumpter (M'23) manager of the J. E. Sumpter Company, Minneapolis, Minn., died July 31, 1933. He was born at Union Grove, Wis., in 1891. Between 1907 and 1908 he was in the meter and repair department of the Mobile Electric Company, and between 1908 and 1909 was student and later in charge of meter testing at Racine, Wis., for the Milwaukee Electric Railway and Light Company. Between 1909 and 1911, he was with the Cosmopolitan Electric Company, Chicago, Ill., as foreman of the meter department. During 1911 and 1912 he was foreman on electrical construction for the Consumers Power Company, St. Paul, Minn., and in 1913 was superintendent of construction of power plants and transmission for the Power Distribution Company, St. Paul. In 1914 he had a similar position with the Sterling Electric Company, and during 1915 and 1916 he was foreman of construction for the Minneapolis General Electric Company. In 1917 he was with the Post Construction Company, Fort Snelling, Minn., and between 1919 and 1920 was executive officer in charge of construction and operation of camp utilities at Camp Dodge and Ft. Des Moines, Iowa. His commissioned rank was captain. In 1921 he became designing engineer in the substation department of the Delta Star Electric Company, Chicago, Ill. In 1922, he organized the J. E. Sumpter Company, at Minneapolis, specializing in substation and transmission structure design, and serving as district manager and engineer for the manufacturers of various lines of high voltage equipment.

Robert Lindsay (A'98) president and general manager of the Cleveland (Ohio) Electric Illuminating Company, died August 25, 1933, at his home in University, Va. He was born in 1869 at Rahway, N. J. In 1887, he started in the testing room of the Edison Lamp Works at Harrison, N. J., working under John W. Howell (A'87, M'88, F'12, member for life and past-manager) Edison's famous associate, after which he was transferred to the instrument department. In 1890 he became assistant to the general manager of the Brooklyn (N. Y.) Edison Company, working under W. S. Barstow (A'94, F'12, life member, and past vice-president). In 1904 Mr. Lindsay went with the Cleveland Electric Illuminating Company, assuming full charge of the construction and operation of the company. He had been with the company continuously since that time, and has been responsible for many engineering developments, and the successful management of the company. Mr. Lindsay was a director of the North American Company, which controls the Cleveland utility. He also was a member of the Edison Pioneers, and of numerous organizations in Cleveland.

Frederick Jessen Rasmussen (A'26) a member of the technical staff of the Bell Telephone Laboratories, New York, N. Y., died August 7, 1933. He was born at Boston, Mass., in 1897. In 1918 he received the bachelor of science degree from Massachusetts Institute of Technology, Cambridge, and interested himself for the succeeding 2 years in the electrolytic refining of copper, tin, and bismuth for the American Smelting and Refining Company, Perth Amboy, N. J. For one year of this period he was in responsible charge of metallurgical operations. In 1921 he joined the engineering department of the Western Electric Company, being first engaged in the mechanical analysis of apparatus. With the formation of the Bell Telephone Laboratories in 1925, he continued in development work, being concerned with electrical measuring apparatus for a while. For some years he has been in charge of the group handling frequency measurements and vacuum tube oscillators and amplifiers for high precision testing.

Employment Notes

Of the Engineering Societies Employment Service

Men Available

Construction

ELEC MAINTENANCE FOREMAN, 32, with 14 yrs practical experience in erection, constrn and operation of industrial plants and mine desires work. Past 4 yrs spent in mining camps in So. Am. Working knowledge German, Spanish. Available immediately. Location immaterial. C-2101

GRAD ENGR, 33, single, 5 yrs experience as electrician on the installation of lt and pwr in large industrial and pub bldgs and 3 yrs on drafting and designing, is seeking connection which will lead into position as cost estimator or constrn foreman with elect contractor. D-2486

Design and Development

B.S. in E.E., Harvard, 1924. Eight yrs with G.E. Co, 5 yrs in research lab with experience involving vacuum technique, elec problems, etc. Would like research or devpt work with small or medium-sized mfg co with opportunity for advancement. Location immaterial. Available immediately D-1486

ELEC ENGR, married, univ grad E.E. and M.E. Twenty-two yrs experience design, constrn pwr plants, substations, transmission, distrn systems; 3 yrs exec experience charge engg dept large util syndicate; 3 yrs purchase engg equipt for foreign interest. Languages English, German, Russian, Armenian and Turkish. Available immediate service design, constrn, operation or purchasing. D-84

INDUCTION MOTOR DESIGNER, elec designing engr with wide experience in designing all types and sizes of induction motors. For the past 20 yrs has been connected with 2 of the country's leading elec mfrs. D-2069

ELEC ENGR, Am, Worcester P. I., Univ of Glasgow, Scotland. One and one-half yrs submarine bldg co; 2 yrs Western Elec Co; 9 yrs Bell Tel Lab. design, lab testing of automatic tel switching systems, 1 yr radio manufacturer. Desires connection where bold and original ideas are in demand. D-1942

ELEC MECH DESIGNER, Assoc. A.I.E.E., 31, 5 yrs design experience abroad substation equipt, oil circuit breakers, automatic switchgears, control apparatus, 1 1/2 yrs design cable accessories, underground pwr transmission, junction boxes, low and high voltage terminals, available at once. Location immaterial. C-5843

Executives

RADIO OPERATOR, radiotelephone, second class, desires connection with any organization using operators licensed for work covered by this type. D-1309

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

57 Post St.
San Francisco

211 West Wacker Drive
Chicago

31 West 39th St.
New York

MAINTAINED by the national societies of civil, mining, mechanical, and electrical engineers, in cooperation with the Western Society of Engineers, Chicago, and the Engineers' Club of San Francisco. An inquiry addressed to any of the three offices will bring full information concerning the services of this bureau.

Men Available.—Brief announcements will be published without charge; repeated only upon specific request and after one month's interval. Names and records remain on file for three months; renewable upon request. Send announcements direct to Employment Service, 31 West 39th Street, New York, N. Y., to arrive not later than the fifteenth of the month.

Opportunities.—A weekly bulletin of engineering positions open is available to members of the cooperating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

Voluntary Contributions.—Members benefiting through this service are invited to assist in its furtherance by personal contributions made within 30 days after placement on the basis of 1.5 per cent of the first year's salary.

Answers to Announcements.—Address the key number indicated in each case and mail to the New York office, with an extra three-cent stamp enclosed for forwarding.

ELEC DESIGN ENGR, 43, married, tech school grad, thoroughly familiar with layout and design of pwr and substations having been connected for past 9 yrs in engg dept of large util. Also experienced, organization and maintenance of meter test dept. Speaks Portuguese. Seven yrs foreign experience. Available immediately. Will go anywhere. C-9886-314-C-14-San Francisco

ELEC ENGR, 42, single, Am. Over 20 yrs experience, design, constr, operation, maintenance and repair of equip in steam and hydroelec pwr stations, substations, transmission lines and factory equip including both elec, mech and other associated work such as foundations, piping, etc. Considerable experience in foreign countries and speaks Spanish fluently. C-502.

ELEC ENGR, 43, married. Cornell Univ grad, also A.B. degree from DePauw Univ. Eight yrs util experience, 4 yrs as mgr of property. Experienced in preparation of appraisals, budgets, financing and genl mgmt problems. Also have had experience in testing motors, elec meters and telephone transmission. Available at once. C-5979

SPECIALIST, E.E. design, constrn—switchboards, metering, protection of apparatus transmission lines, distrn systems. Consider position, investigator insurance co—maintenance engr elec control of steam boiler auxiliaries, familiar Bailey, L&N Co. & Hagan controls, control engr for conveyor equip co and control of automatic machines. Twenty-five yrs experience, 9 yrs S. & W. Engg Corp. B-7290

TRACTION ENGR, 29, single, 5 yrs experience on elec-traction shops as inspector, since then and at present in charge of serv of Southeast on registers. Two yrs at Ga. Tech, later graduated in E.E. from the I.C.S. Was radio operator. Desires position as asst engr for elec traction. D-80

GRAD E.E., 15 yrs engg experience with pwr co, now employed, desires to make a change; location desired Middle West. C-964

E.E., 35, 10 yrs experience covering plant design, estimating, specifications and field work of central stations, substations, transmission lines, metallurgical plants and industrial bldgs. Also 1 yr cable research work and 1 yr elev testing. Licensed N. J. engr; English and German languages. Available immediately. C-5473

PLANNING ENGR, 2 yrs Westinghouse; 2½ yrs util transmission planning. Univ of Ill grad, B.S. Available immediately. Location immaterial. C-9381

TECHNICAL TRAINED MAN, 33, single, 10 yrs experience in lt and pwr distrn of high class bldgs. Layout and specifications, contracting and supervision of constr. Partner of cons engg firm in N. Y. City for 4 yrs. Exec ability, highest references. Desires position with future. Location immaterial. D-2519

E.E. AND DESIGNER, 47, married, univ grad. Two yrs G.E. test and lab, 18 yrs experience on design, production and manufacture with larger cos, mainly on transformers and similar apparatus. Eighteen mos on devpmt of resistance welding machy. Some experience in exec capacity. C-8806

ENGG EXEC in any of the following lines: food preparing machy, mech and elec research in food or textile industry or any related elec industry. Graduate E.E., educated in German Univ. Age 33, married. Ten yrs devpmt and factory experience, possess good personality, adaptability, foresight and have held responsible positions. C-4160-4793-Chicago

Instruction

ASSOC OR ASST PROF OF E.E., 34, B.S. in E.E. and M.S. in E.E. Five yrs teaching experience leading tech school, 3 yrs as asst prof; 4 yrs in charge of education and training for natl tech corp. Any location. C-8967

ENGG INSTRUCTOR, 33, single, mechl and elecl degrees, specializing in mech design, mathematics, etc., 4 yrs instr at Cornell Univ followed by 5 yrs practical design work for Allis-Chalmers. Salary open. D-122

Junior Engineers

JR ENGR, B.S. in E.E., 1933, Va. Poly Inst, 22, single, Pi Delta Epsilon. Col work in pwr. Especially interested in engg journalism, tech report work, etc; 2 yrs experience assisting in editing 3 col publications. Location immaterial. Excellent references. Available immediately. D-2426

PURDUE GRAD, 1929, B.S. in E.E., 26, single. Six mos with radio mfr; 1 yr extensive util training course, 6 mos in engg office. References. Desires employment with util or mfr. D-1801

STATISTICIAN, 27, single, B.S. in E.E.; correspondence work in bookkeeping; passed local civil serv examination; can arrange interview any Pacific Coast city. Available 1 mo. Location West or Alaska. D-2463-338-C-1-San Francisco.

B.S. in E.E. 1932, Missouri Schl of Mines, specializing pwr engg with communication minor, 22, single. Desires work, laborer or professional, elec field with chances for advancement. Three mos experience elec refrigeration G.E. Co. Unemployed since graduation. Not afraid to work. Go anywhere in U.S. Salary immaterial. Available immediately. Good references. D-2464

B.S. in E.E., Lafayette Col, 1933, single, 21. Tau Beta Pi, secy-treas student branch of A.I.E.E.; desires position in elec field, preferably research. Location and salary secondary. Available immediately. D-2489

E.E. GRAD, Armour Inst. Eta Kappa Nu. Single, 24. Exp in installing, wiring, and testing automatic telephone exchange switchboards; 4 yrs util experience as substation operator and distrn dept, incl. latest in mercury arc rectifiers, ry, d-c, and a-c distribution systems. Location immaterial. Desires growing connection. D-2528

ELEC ENGR, E.E. deg, young, formerly in charge of field office for Federal Radio Commission; with teaching, research, administrative, operation, inspection and pub relations experience, desires opportunity wherever sterling character and experience may be profitably utilized. Character references from major executive available. D-1804

B.E.E. 1931, U.D. coöperative course, 26, single. Earned the major part of col expenses. Four yrs elec constrn; 2 yrs stadium ltg; ½ yr inspection. Would like any type of engg work with opportunity for advancement. Will go anywhere at once. D-1060

E.E., 1933, R.P.I., 21, single. Member of Sigma Xi. Some experience in business office and elec mfg co. Can type. Specialized in pwr and lt engg. Conscientious worker. Location, character of work, salary immaterial. Best references. D-2467

B.S. in E.E. Brown Univ, 1933, 22, single. Specialized in electronics. Two yrs part time with Elec Research Products, Inc. Industrious and willing to take any position in E.E. line affording experience and possible advancement. Best references. Any location although East preferred. Available immediately. D-2523

B.E.E., Polytechnic Inst. Bklyn, 1933, single, 21. Tau Beta Pi. Honor student. Grad with honors. Desires experience and opportunity in E.E. field. Preference for N. Y. C. location. Salary secondary. Avalable immediately. D-2526

B.S. in E.E., R.P.I., 1932, with honors, 22, single. Experience in radio servicing, amateur radio. Desires position in any elec field. Available immediately. Location and salary immaterial. D-2524

B.S. in E.E. 1930, M.S. in E.E. 1931. Married, 25, no physical defects. M.S. deg with honors. Experienced in gen elec serv and constr; 1 summer in relay dept pwr co, 1 yr teaching elec. Any kind of elec refrg, or air cond work is greatly needed. D-1198

B.S. in E.E. 1932, 25, single. Desires any type of E.E. work. Available immediately. Salary secondary, location immaterial. D-1559

E.E. GRAD, 1931 coöperative school, 2½ yrs pwr plant, switching station, and substation constrn, and maintenance, 1½ yrs meter testing. Desires connection with util, industrial or elec ry co. Location and salary optional. Will do anything. D-2531

Maintenance and Operation

PLANT OR MAINTENANCE ENGR, M.E. Cornell, married. Practical experience for 15 years in application, maintenance, design and building of manual and automatic elec equip for industrial and central stations together with thorough knowledge of maintenance materials qualifies me for a permanent connection. Salary requirements in line with today's conditions. D-1273

Research

DEVELOPMENT ENGR who has demonstrated inventive and exec ability as chief engr of co leading its field; 20 yrs experience with design and manufacture of all types of motors and motor driven machy. Served as director and can assist sales dept. Alex. Hamilton Inst., 2 deg, honors, Ill. D-404

Sales

SALES ENGR, E.E. deg, 31, single; 3½ yrs high grade sales experience selling mfrs, industrials and educational institutions, contacting distributors' branches, etc. Excellent correspondent. Several years' engg dept large util, also several yrs elec testing. Underwriters' Laboratories; some electrical contracting. Interested, desirable opening anywhere. Moderate remuneration. Available immediately. D-1344

Membership

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before October 31, 1933, or December 31, 1933, if the applicant resides outside of the United States or Canada.

Ashford, G. W., A. & M. Col. of Texas, College Station.
Ballard, B. A., Nat. Res. Council Ottawa, Can.
Barrow, W. L. (Member), Mass. Inst. of Tech., Cambridge.
Chandesh, C., E-J Elec. Installation Co., New York City.
Gale, L. G. (Member), James Wilkinson & Co., Boston, Mass.
Guice, F. J., Memphis Pwr. & Lt. Co., Tenn.
Killgore, C. L., Babcock & Wilcox Co., Boulder City, Nev.
Lehmann, H. G., 109 Columbia St., Bergen Co., Woodridge, N. J.
McNellis, B. J., 35-11 21 Ave., Astoria, L. I., N. Y.
Robinson, E. E., Ill. Pwr. & Lt. Corp., Kewanee.
Sanborn, C. A., Lab. of Ford Instrument Co., Inc., L. I. City, N. Y.
Schwerdtfeger, W. J., Pub. Serv. Corp., of N. J., Harrison.
Steckler, H. A., Henry A. Steckler, Inc., New Orleans, La.
Timoshenko, G S., Univ. of Mich., Ann Arbor.
Weber, C. H. (Member), The Chesapeake & Potomac Tel. Co. of Va., Richmond.

Wilcox, R. B., Gen. Cable Corp., N.Y. City.
16 Domestic

Foreign
Heyne, H. (Member), c/o Koch & Sterzel, Dresden, Germany.
Mehrotra, J. P., c/o Messrs. Kalyan Singh & Sons, Balrampur, India.
Torrance, A. E., Municipal Electricity Dept., Port Elizabeth, So. Africa.
3 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Blackhall, Harold J., Postlagernd, Essen, Germany.
Bugnion, Frank E., 14 Clinton St., Cambridge, Mass.
Collins, H. Stanley, 100 Carlson Road, Rochester, N. Y.
Endicott, E. M., 2020 Monroe St., Toledo, Ohio.
Hamby, H. M., 708 F St., N. E., Washington, D. C.
Ingles, J. A., c/o Trans. Dept., H. E. P. C., MacLean Bldg., Toronto, Ont., Can.
Jones, Edgar A., 2590—35th St., Astoria, L. I., N. Y.
Lober, Charles, K. C. P. & L. Co., 1330 Baltimore Ave., Kansas City, Mo.
Moller, Thure B., c/o Gibbs & Hill, Penn City Sta., New York City.
Moore, Everett, 2479 Kalakawa Ave., Honolulu T. H.
Mowat, George, 230 Mather St., Oakland, Calif.
Perkins, T. S., 154 Maple St., Springfield, Mass.

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, during July are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface or text of the book in question.

COMMON SENSE about MACHINES and UNEMPLOYMENT. By M. P. Taylor. Phila., Chicago, Toronto, J. C. Winston Co., 1933. 173 p., 8x5 in., cloth, $1.50. Argues that mechanization of industry has directly reduced employment and indirectly reduced trade, not as a necessary effect but by unbalancing production and consumption. If the latter were kept adjusted, machinery would improve the average standard of living and advance material civilization. Discusses the reasons why we have failed to use machinery properly, and examines the remedies that have been proposed.

DEBT and PRODUCTION, the Operating Characteristics of Our Industrial Economy. By Bassett Jones. N. Y., John Day Co., 1933. 147 p., illus., 9x6 in., paper, $2.00. Discusses production, employment, price, and the relation of debt to production. Many assumptions in standard statistical works are criticized adversely. Mr. Bassett Jones concludes that physical production and debt have been growing at differential rates until a point has been reached where production can no longer carry the load of debt imposed upon it. Contains an "introduction" occupying 2/3 of the book, which presents in plain English the conclusions drawn from his mathematical analysis.

DIFFERENTIAL EQUATIONS for ELECTRICAL ENGINEERS. By P. Franklin. N. Y., John Wiley & Sons, 1933. 299 p., illus., 9x6 in., cloth, $2.75. Assumes only the knowledge of ordinary differential equations usually included in a first course in the calculus. Treats of the ordinary differential equations which arise in determining the flow of current in a network with lumped constants and with some formal knowledge of complex numbers and Fourier series. Contains an elementary working knowledge of partial derivatives and partial differential equations. A section of a more theoretical nature is devoted to analytic functions and the convergence of Fourier series.

DIRECT and ALTERNATING CURRENTS, Theory and Machinery. By E. A. Loew. N. Y. & Lond., McGraw-Hill Book Co., 1933. 656 p., illus., 9x6 in., cloth, $4.50. Intended primarily for students desiring a short survey course in the theory of the electric circuit and the operating principles of electric machines. Fundamental principles, rather than factual data predominate in the work.

ELECTRON TUBES and THEIR APPLICATION. By J. H. Morecroft. N. Y., John Wiley & Sons, 1933. 458 p., illus., 9x6 in., cloth, $4.50. Treats generally of the extraction of electrons from matter and the methods of utilizing them. Discusses the characteristics and applications of all types of commercial tubes. The field is covered in reasonably thorough fashion, with full attention to the industrial uses of electron tubes, and is written in a style that will enable the average engineer to master its contents.

GRUNDLAGEN und ENTWICKLUNG der ENERGIEWIRTSCHAFT ÖSTERREICHS. Offizieller Bericht des Österreichischen Nationalkomitees der Weltkraftkonferenz. *Ergänzungsband 1930–1933.* By O. Vas. Vienna, Julius Springer, 1933. 84 p., illus., 11x8 in., paper, 4.80 rm. At the Berlin world power conference in 1930 the Austrian committee presented a comprehensive report on the power resources of Austria. The present volume, prepared for the Scandinavian sectional meeting of 1933, is a supplement to that report, which describes developments during the intervening years. Fuels, water power, electrical plants, distribution systems, and regulation are discussed.

HANDBOOK of MATHEMATICAL TABLES and FORMULAS. Compiled by R. S. Burington. Sandusky, Ohio, Handbook Publishers, 1933. 251 p., 8x5 in., lea., $2.00. Provides, in one compact volume, the mathematical formulas and tables needed by engineers, physicists and students of mathematics. It contains the more important formulas and theorems of algebra, trigonometry analytic geometry, calculus and vector analysis, a comprehensive table of series, derivatives and integrals, and also 5-place logarithmic and trigonometric tables.

NATIONAL PHYSICAL LABORATORY REPORT for the YEAR 1932. London, Dept. of Scientific and Industrial Research. (N. Y., British Library of Information.) 1933. 277 p., illus., 11x9 in., paper, 14s 0d. Describes the research work of the year in physics, electricity, metrology, engineering, metallurgy, and naval architecture. The reports are in sufficient detail to be valuable and are illustrated by photographs and drawings.

PRINCIPLES of INDUSTRIAL ORGANIZATION. By D. S. Kimball. 4 ed. N. Y. & Lond., McGraw-Hill Book Co., 1933. 460 p., illus., 9x6 in., cloth, $4.00. The scientific background of production and the methods and mechanisms of management that have been devised to control it are clearly and concisely presented in this textbook for engineering students. The new edition has been thoroughly revised, but has been kept to a reasonable size, suited to instructional uses.

PRINCIPLES OF MOTOR TRANSPORTATION. By F. K. Edwards. N. Y. & Lond., McGraw-Hill Book Co., 1933. 377 p., illus., 9x6 in., cloth, $4.00. A comprehensive study of the problems of freight and passenger transportation. Methods of development, organization, and operation, maintenance problems, rate making, valuation and regulation are discussed. The practises of successful operators are described.

PUBLIC UTILITIES and the PEOPLE. By W. A. Prendergast. N. Y. & Lond., D. Appleton-Century Co., 1933. 379 p., 8x6 in., cloth, $3.00. The former chairman of the public service commission of the State of New York presents a timely discussion of utility companies in general and electric utilities in particular. Such controversial questions as the "power trust," holding companies, valuation, rates, regulation and public ownership are considered fully.

SPANNUNGSREGELUNG mit GLEITTRANSFORMATOREN. By O. Löbl and N. Hammerl. Berlin, Julius Springer, 1933. 20 p., illus., 8x6 in., paper, 2 rm. Describes a new type of voltage regulator in which the relative position of the primary and secondary windings is adjusted by sliding one past the other. The regulator is described briefly, its uses indicated and some examples shown.

STEAM, AIR, and GAS POWER. By W. H. Severns and H. E. Degler. 2 ed. N. Y., John Wiley & Sons, 1933. 480 p., illus., 9x6 in., cloth, $4.00. An elementary text for use in courses in heat engineering where only a limited amount of work in the subject can be included. Describes typical equipment, and explains the theory of such machines and devices. Only simple mathematical calculations are used. The new edition has been rearranged and revised, and the problems have been replaced by new ones.

SYMMETRICAL COMPONENTS as Applied to the Analysis of Unbalanced Electrical Circuits. by C. F. Wagner and R. D. Evans. N. Y. & Lond., McGraw-Hill Book Co., 1933. 437 p., illus., 9x6 in., cloth, $5.00. This, the authors assert, is the first text which gathers together the fundamental theory underlying this generally accepted method, and discusses its principal applications. The book is intended for practising engineers and graduate students. A bibliography is included.

VALUE THEORY and BUSINESS CYCLES. by H. L. McCracken. N. Y., Falcon Press, 1933. 270 p., charts, 9x6 in., cloth, $4.00. Recent years have produced many books on business cycles and price movements, in which highly divergent and often contradictory views have been presented. This, in this writer's opinion, is because of a failure to recognize that price movements and business cycles are problems in value theory. The present book is devoted to make the vital relationship clear.

WHAT ELECTRICITY COSTS, in the home and on the farm; a Symposium. Edit. by M. L. Cooke. N. Y., New Republic, Inc., 1933. 231 p., illus., 8x5 in., paper, $1.00. This volume contains papers presented before the Institute of Public Engineering on January 20, 1933. The meeting was devoted to the cost of distributing electrical power and various phases of this subject are here discussed by experts. The book contains much of value upon the measurement of distribution costs, the present status of cost finding and the relations of cost to use.

ACCOUNTING MANUAL for SMALL CITIES. (Publication No. 1.) By C. H. Chatters. Chicago, Municipal Finance Officers' Assn. of the U.S. and Canada, 1933. 79 p., charts, tables, 10x7 in., paper (no price given). This pamphlet describes a system of accounting adequate to the needs of cities under 25,000 population. The necessary accounting statements, the books to be kept, the accounts, the relation of the accounting system to allied activities, and journal entries are discussed. Samples of the necessary forms are given. The book is issued by the Municipal Finance Officers' Association.

ELECTRICAL CIRCUITS and MACHINERY. V. 1. Continuous Currents. By J. H. Morecroft and F. W. Hehre. 2 ed. N. Y., John Wiley & Sons, 1933. 457 p., illus., 10x6 in., cloth, $4.00. Starting with a thorough presentation of the fundamental principles of electric and magnetic circuits, this textbook for elementary undergraduate courses proceeds to an analysis of the more important machines and equipment used in continuous-current engineering. The work includes the information wanted by the average student in any branch of engineering, is clearly written and well illustrated. The new edition has been revised and modernized.

ENGINEER'S MANUAL of ENGLISH. By W. O. Sypherd and S. Brown. Chicago, Atlanta, Dallas, and N. Y., Scott, Foresman & Co., 1933. 515 p., illus., 7x5 in., lea., $2.00. The first half of this work is a concise textbook of English composition, in which emphasis is placed upon correspondence, reports, articles, bulletins, specifications and other forms of writing with which engineers are especially concerned. The second contains specimens of engineering writing, for study and analysis.

Engineering Societies Library

29 West 39th Street, New York, N.Y.

MAINTAINED as a public reference library of engineering and the allied sciences, this library is a cooperative activity of the national societies of civil, electrical, mechanical, and mining engineers.

Resources of the library are available also to those unable to visit it in person. Lists of references, copies or translation of articles, and similar assistance may be obtained upon written application, subject only to charges sufficient to cover the cost of the work required.

A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

Industrial Notes

Charles F. Norton Joins Allis Co.—Chas. F. Norton, former vice-president and general manager of the Howell Electric Motors Co., has become associated with The Louis Allis Co., Milwaukee, in an executive sales capacity.

Ohio Brass Awarded Large Insulator Order.—The Ohio Brass Company, Mansfield, Ohio, has been awarded the contract for 253,000 suspension insulators by the Bureau of Power and Light, City of Los Angeles, for the 270 mile, 275-kv power transmission line between Boulder Dam and the City. The insulator contract is one of the largest ever awarded, amounts to approximately $435,000, and calls for deliveries from January 1, 1934, to January 1, 1935, on which production has been started in both the Mansfield and Barberton plants. The former will supply 325 tons of malleable iron caps which will be assembled with the porcelain parts made in the Barberton plant from which will be shipped a total of 75 carloads of completed insulators.

G-E Now in Own New York Building.—The General Electric Company and four of its associated companies have moved their offices in New York City to the new General Electric Building, 570 Lexington Avenue at 51st Street. Included are the executive offices, New York district office, air conditioning department, electric refrigeration department, Atlantic division of the incandescent lamp department, merchandise department, and plastics department, the International General Electric Company, Inc., and other affiliates. Approximately one-half of the new building, which is 50 stories high, is occupied by the company. Fourteen of the General Electric offices in the new building have been furnished with air conditioning equipment.

New Oil Circuit Breaker.—The Delta-Star Electric Company, Chicago, Ill., has developed a new rectangular tank type "CR-30AT" 15 kv, 600 amp, three pole breaker with an interrupting capacity of 50,000 kva at rated voltage. The fabricated steel head is heavily gridded on the inside and the Lamphenite insulated studs are cross braced with treated wood. Lift rods are guided by rollers and cross-tied to insure positive contact and alignment. The main contacts are silver surfaced and self-contained shock absorbers absorb impact forces. Main shaft bearings are bronze bushed. A multipart oil retractor separates the oil from the gases during arc extinction, allowing the latter to be carried away through a header.

New Texsteel Texrope Drive Ratings.—Allis-Chalmers "Texrope" V-belt drive with one or both sheaves "Texsteel" are now available from $^1/_4$ to 15 hp, suitable for many industrial applications. Texsteel sheaves are grid type construction, with accurately formed heavy gauge steel sections electrically welded at web and rim. Outer rims are rolled for protection, good appearance and strength. Integral bushings or solid bored hubs are standard. Texsteel sheaves are well-balanced, light in weight and practically indestructible. Texsteel Texrope drives are particularly economical where large numbers of V-belt drives are required or, as standard equipment for machinery manufacturers. The Texsteel sheaves have an attractive aluminum finish.

New Magnetic Starter.—For motors up to 15 hp, 220 volts, and 30 hp, 440–550 volts, the Electric Controller & Mfg. Company, Cleveland, has developed its type ZOS oil-immersed, across-the-line, combination magnetic starter, containing an unfused or fusible safety switch, a magnetic starter with overload relays, and heavy duty test jacks for those applications where it is desired to insert meters in the motor circuit without interrupting the operation of the machine. All of the internal wiring of these starters is complete. Although designed for the severe service encountered in mill duty, these starters are exceptionally small and narrow, having safety switch front operation and a cover that swings vertically. This makes them especially desirable for mounting in restricted spaces such as between the flanges of columns, for mounting on motor driven machines or where many starters are closely grouped along a wall.

New Clip-On Ammeter.—Ferranti, Incorporated, New York, who a little over a year ago brought out a dual range 0/100–0/500 ampere standard clip-on ammeter, now announce a new model which, instead of being supplied in the single combination of 0/100 and 0/500 amperes, can be furnished with single or dual ranges in any combination of from 7.5 to 1000 amperes, the first point on the scale in each case being 10% of full range. The lower range clip-on ammeters are slightly more expensive due to the use of a special highly accurate instrument. However, extreme accuracy is thus obtained and the current consumed by small motors, etc., can be accurately and quickly recorded. Any of the clip-on ammeters can be placed around an insulated or uninsulated conductor leading to a motor, transformer, etc., etc., and the current quickly measured without shutting down the load or disconnecting the circuit in any way. The handle of the instrument is insulated from a bare copper conductor placed in the window of the magnetic circuit for 15,000 volts, so the meter may be used with safety as well as convenience and accuracy.

Outdoor Meter Box.—A new, exceptionally compact, aluminum outdoor meter box has been introduced by the Switch and Panel Division, Square D Company, Detroit, Mich. The box is only 15$^3/_4$ inches high by 8 inches wide and 8 inches deep. The wiring method indicates entrance of the service through the top. Load wires are then brought out through the bottom or the back of the box, as preferred. Ample wiring space is available due to the fact that the meter and the test block are elevated from the back of the box permitting wires to be run underneath. The new test block is only 2$^{11}/_{16}$ inches high by 5$^5/_{16}$ inches wide, employing the sequence of "two-in, two-out"—the line connections being brought into the meter through the two left-hand legs and the load through the two right-hand legs. Semi-rigid meter connectors permit the meter terminal chamber to slide down over them with ease. Testing is accomplished by means of jumpers. Test links are provided in each leg of the test block. Test clips are included with the block. Special sealing arrangements have been provided for, with provisions for a glass seal, if desired. The new unit is listed as standard by the Underwriters Laboratories.

Trade Literature

Balancing Machine.—Bulletin, 4 pp. Describes the Olsen vibro-electric, self-indicating, static-dynamic, balancing machine, style "E-O," suitable for balancing the rotors of the smallest motors with great accuracy and speed. Tinius Olsen Testing Machine Co., 500 North 12th St., Philadelphia, Pa.

Vertical Motors.—Bulletin 174, describes three different types of vertical motors, and by means of illustrations of applications explains how horizontal-type motors can be mounted vertically, thus saving the cost of special vertical construction. Wagner Electric Corp., 6401 Plymouth Ave., St. Louis.

Valves.—Catalog 23, 264 pp. Describes 400 Jenkins valves in a wide range of types and patterns. All features of design and construction are clearly and fully outlined. Services, pressures, temperatures and fluids for which the valves are recommended are included. The last section of the book contains many pages of engineering data usually required when valves are specified. Jenkins Bros., 80 White Street, New York.

Surge Protection Equipment.—Catalog 38, 96 pp. Describes the complete line of Westinghouse surge protection devices. Listed new equipment includes watthour meter protectors, transformer gaps and neutral arresters, De-ion relief gaps, surge protection for rotation machines, and surge generators. All the necessary information to aid in buying equipment is included such as discussion of the application, prices, instructions for ordering, approximate multipliers, style number index, etc. Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Switchboard Instruments.—Bulletin MS-1, describes a new line of a-c and d-c switchboard instruments and switchboard panels. Instruments of type E-45 are suitable for the highest type of switchboard work, type S-30 being used where smaller and lower cost meters are desired. The former measure 5 inches across front flange, and the latter 2$^5/_8$ inches. Four standardized types of panels, to meet average requirements, are listed; special designs being supplied to order. Columbia Electric Mfg. Co., 1292 East 53rd St., Cleveland, Ohio.